Bioversity International

Bioversity International
Celebrating 45 Years of Agrobiodiversity Research

45th anniversary

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Celebrating 45 Years
of Agrobiodiversity Research

Contents

Juan Lucas Restrepo

2019–today: Director General, Bioversity International/CEO-Designate of the Alliance

Juan Lucas Restrepo Welcome

This book looks back on 45 years of excellence in research for development since Bioversity International was established in 1974 as the International Board for Plant Genetic Resources. It is the result of a crowdsourced approach with short contributions written by past and present staff members, Directors General and Board Chairs.

With 45 years to select from, this book is not an exhaustive documentation of our work, but a representative sample chosen to celebrate some important moments, themes and characters over the years. We hope it gives a sense of the passion and rigour that we have for safeguarding and using agricultural biodiversity as the foundations of agriculture and food systems.

Today it is widely accepted that we need to fix the food system and that this change must include a greater use of agricultural biodiversity on our farms and on our plates. The landmark 2019 *EAT–Lancet Commission on Healthy Diets from Sustainable Food* says: “Food in the Anthropocene represents one of the greatest health and environmental challenges of the 21st century,” and recommends that “production needs to focus on a diverse range of nutritious foods from biodiversity-enhancing food production systems rather than the increased volume of a few crops.”

As the reader will learn when reading this work, our story is full of change that allowed us to adapt to the external environment and challenges we were faced with, a quest that has been successful for the past 45 years. It is an honour for me to take over the reins of Bioversity International at this time, as we move towards establishing an Alliance with the International Center for Tropical Agriculture (CIAT). Again, as we have done many times during our history, we address decisively this new opportunity to perform better and further meet our vision and dreams. I am sure we will continue to draw on our experience and past success in building our Alliance.


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Julia Marton-Lefèvre

Chair, Board of Trustees, Bioversity International

Julia Marton-Lefèvre Welcome

I have served as the Chair of Bioversity International's Board of Trustees from 2016 – a role that is both a pleasure and an honour.

During my tenure, I have got to know many of the members of Bioversity International's staff, and I am consistently impressed by the talent, energy and commitment of the researchers and the people providing operational support to deliver important results on the ground. Bioversity International has every reason to be proud of its 45-year history of nourishing people in a way that continues to sustain our planet.

For the past year we have focused not only on strengthening Bioversity International's capacity but in building an Alliance with a sister CGIAR Research Centre, the International Center for Tropical Agriculture (CIAT). Uniquely, we entered into these discussions to explore a strong stratewe gic partnership to enhance our impact to achieve food systems and landscapes that sustain the planet, drive prosperity and nourish people.

In 2018, we signed a Memorandum of Understanding that outlines the common mission, vision and strategic objectives of the Alliance. The Alliance will build on Bioversity International's history, along with CIAT's 52 years, with the view that together we will be able to seriously increase the impact of our mission and our work.

In this anniversary year we said farewell to Ann Tutwiler, who served as Director General, Bioversity International, since 2013. On behalf of the Board and staff, we extend our sincere appreciation for her leadership and dedication during her tenure.

We also extend a warm welcome to Juan Lucas Restrepo, the new Director General of Bioversity International and Chief Executive Officer-Designate of the Alliance. Restrepo joins us from Agrosavia, the Colombian Corporation for Agricultural Research, bringing decades of experience and a proven record of accomplishment improving the capacity, quality, effectiveness and impact of agricultural research-for-development organizations.

I congratulate Bioversity International on its first 45th year and look forward to celebrating continued successes in the years to come.

Our journey so far

Genetic diversity of food crops has been at the heart of Bioversity International's mission for its 45 years of existence, since it was established as the International Board for Plant Genetic Resources (IBPGR). From an initial focus on collecting and conserving crop genetic resources, over the decades our research agenda has evolved, with each evolutionary step adding a new perspective on plant genetic diversity research. Our name has evolved too to reflect changing priorities, first to the International Plant Genetic Research Institute (IPGRI) in 1993, and then merging IPGRI with the International Network for the Improvement of Banana and Plantain (INIBAP) to form Bioversity International, emphasizing our interest in the contributions of agricultural biodiversity beyond plant genetic resources. Each additional perspective maps roughly to one of our four current strategic objectives: safeguard, plant, produce and consume. Our work began as a coordinating role, supporting national programmes in their endeavours, and this has largely remained our *modus operandi*, conducting research in response to national and global concerns through networks and partnerships.

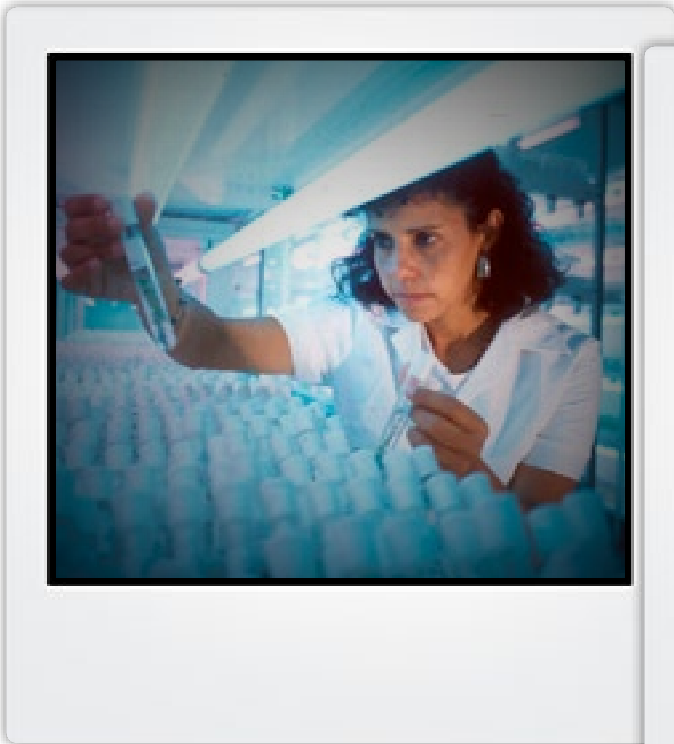
Safeguard (1974–present)

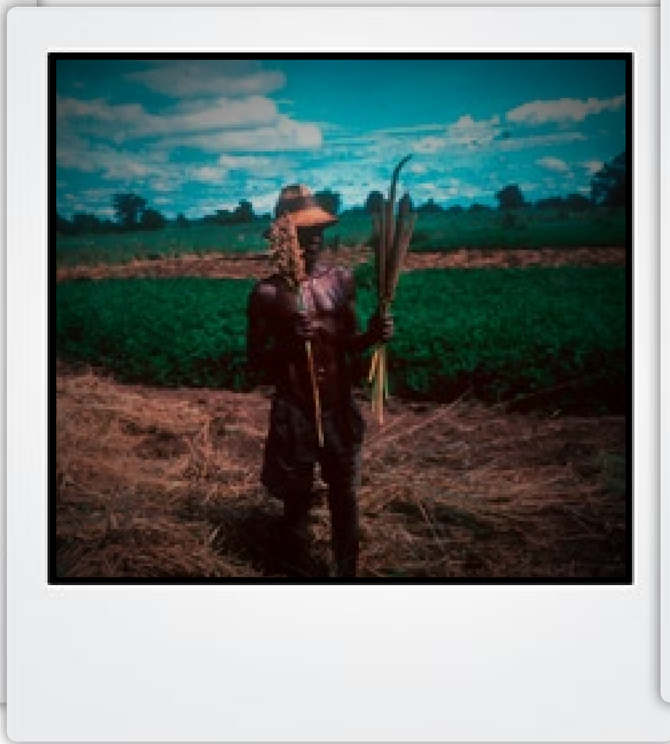
The original Terms of Reference established for Bioversity International (as IBPGR – the International Board for Plant Genetic Resources) were remarkably long-sighted. They set the foundations for the work of the organization for the following 45 years through its various incarnations. Ten years into the Green Revolution, it seemed that modern high-yielding crop varieties would sweep through the world's fields wiping out traditional farmers' varieties of the major crops. The success of modern breeding was undermining its own future by eliminating the genetic diversity on which breeders depend. IBPGR set out on a race against time to collect as much genetic diversity as possible of priority crops (primarily major food crops) and to ensure it was conserved for posterity.

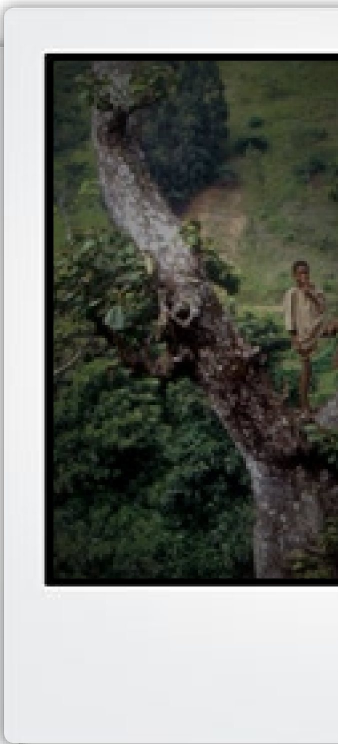
In 1974, there were about eight genebanks around the world. Over the next decades IBPGR assisted in the establishment of genebanks all over the world, trained hundreds of scientists who went on to run these genebanks, and developed conservation protocols and genebank standards. We coordinated regional and global network conservation activities, supported collection of threatened germplasm and organized research on priority problems. During the early 2000s, IPGRI helped establish the Crop Trust to ensure the long-term financing of the major genebanks through an endowment fund.

Although IBPGR was not initially set up as a research centre, soon research began because we needed to understand how best to store seeds for long periods. We investigated the optimal storage conditions for seeds that can be stored under cold dry conditions (orthodox seeds). Another question was how to conserve crops whose seeds are more challenging to preserve, or which do not have seeds at all. This almost 30-year programme of work on *in vitro* storage and cryopreservation included studies at our banana genebank, the Bioversity International *Musa* Transit Centre (ITC) in Belgium, which is now one of the most significant repositories of cryopreserved germplasm in the world. Another research challenge was to understand the extent and distribution of genetic diversity, and the threats to it, in order to prioritize what to safeguard.

From an original focus on safeguarding major food crops in genebanks, our conservation focus started to widen from the mid-1990s in four major ways. The first is that it now includes hundreds of crop species of great local importance but largely neglected. The second is a focus on conservation of valuable tree genetic resources and the wild relatives of crops *in situ* in their natural surroundings. The third is a growing focus on safeguarding agricultural biodiversity on farm at different levels, from genetic diversity through to landscape diversity. The fourth is a global mandate on safeguarding banana diversity, following the 1994 merger with INIBAP.







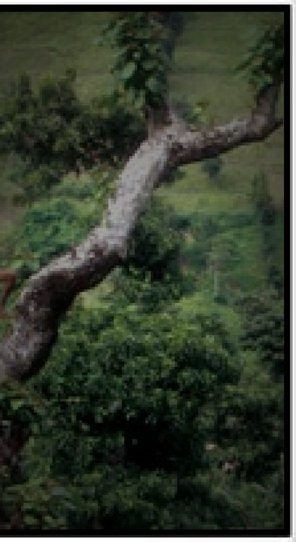
Plant (1987–present)

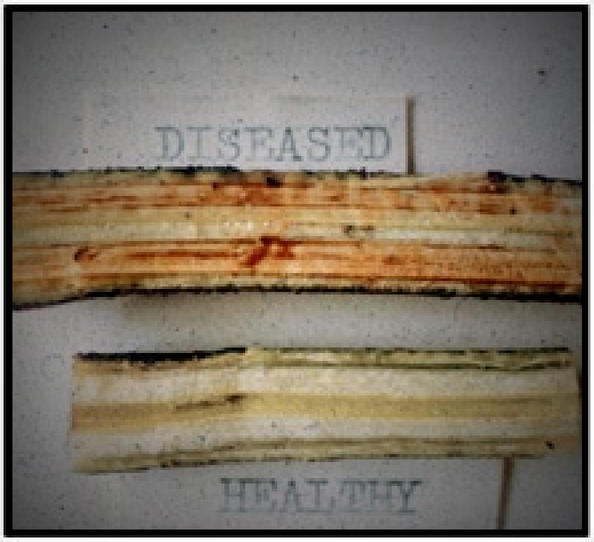
1987 saw the start of a new strategy for the International Board for Plant Genetic Resources (IBPGR). While collecting and safeguarding activities had always been carried out with breeders in mind, the links to use, in other words getting materials in farmers' hands and planted in fields, had not been explicitly addressed. From the late 1980s, the organization focused on different ways of strengthening the interface between germplasm conservation and its use. New activities focused on characterizing and describing the diversity, and developing systems to provide access to this information and material. Over the years, we produced descriptors for over 100 crop species, providing a common language for cataloguing collections. We developed information systems, like the *Musa* Germplasm Information System. The System-wide Information Network for Genetic Resources (SINGER) brought all the CGIAR genebanks' online databases together.

Public awareness was a new foray. We launched the newsletter *Geneflow*, and participated in many global events such as the Rio Earth Summit in 1992. We started to translate research into action by integrating research results into training programmes, including a long collaboration with the University of Birmingham. We also carried out capacity strengthening through fellowships in which researchers could tackle a biodiversity-related question in agriculture or natural resource management.

We expanded our research on using genetic resources to understand seed systems and how germplasm flowed from one place to another, including traditional knowledge about the crop varieties and species and their management and uses, and gendered knowledge systems.

At the same time, we were providing technical and legal support to countries to ensure that they could easily transfer disease-free requested materials and, where appropriate, to facilitate the return of benefits to the originating country. The late 1980s witnessed a shift in the global paradigm for considering plant genetic resources from a principle of a common heritage for [hu]mankind to a principle of national sovereignty, with subsequent decreasing access. When the Food and Agriculture Organization of the UN (FAO) and national governments, in response to this shift, started to work on an International Treaty for Plant Genetic Resources for Food and Agriculture and a Multilateral System for sharing germplasm, we provided critical technical support.





Produce (1994–present)

A turning point came in 1993, with a new name, the International Plant Genetic Resources Institute (IPGRI). This came with a new strategy 'Diversity for Development' and a broader approach, which took account of socioeconomic and cultural aspects of conserving plant genetic resources. This reflected growing global concerns about sustainable development and a new multilateral biodiversity treaty, the Convention on Biological Diversity, opened for signature by countries at the 1992 Rio Earth Summit. We began a work programme lasting over 20 years across nine countries to understand on-farm conservation.

Until now, we had thought that the greatest threat to conservation of genetic diversity was that farmers were abandoning traditional varieties for improved ones. This proved not to be the only reason. Yes, genetic diversity at all levels was under threat – from urbanization, climate change, changing consumer demand – but repeatedly we found that smallholder farmers maintained their own varieties alongside modern ones in integrated systems. Farmers valued their heritage varieties for many reasons: for example, taste, resilience to drought or pests, low input needs and cultural practices. This discovery transformed our research agenda: agricultural biodiversity has importance beyond its indisputable value as a source of traits for breeders, and one way to conserve it is to enhance those immediate benefits to farmers.

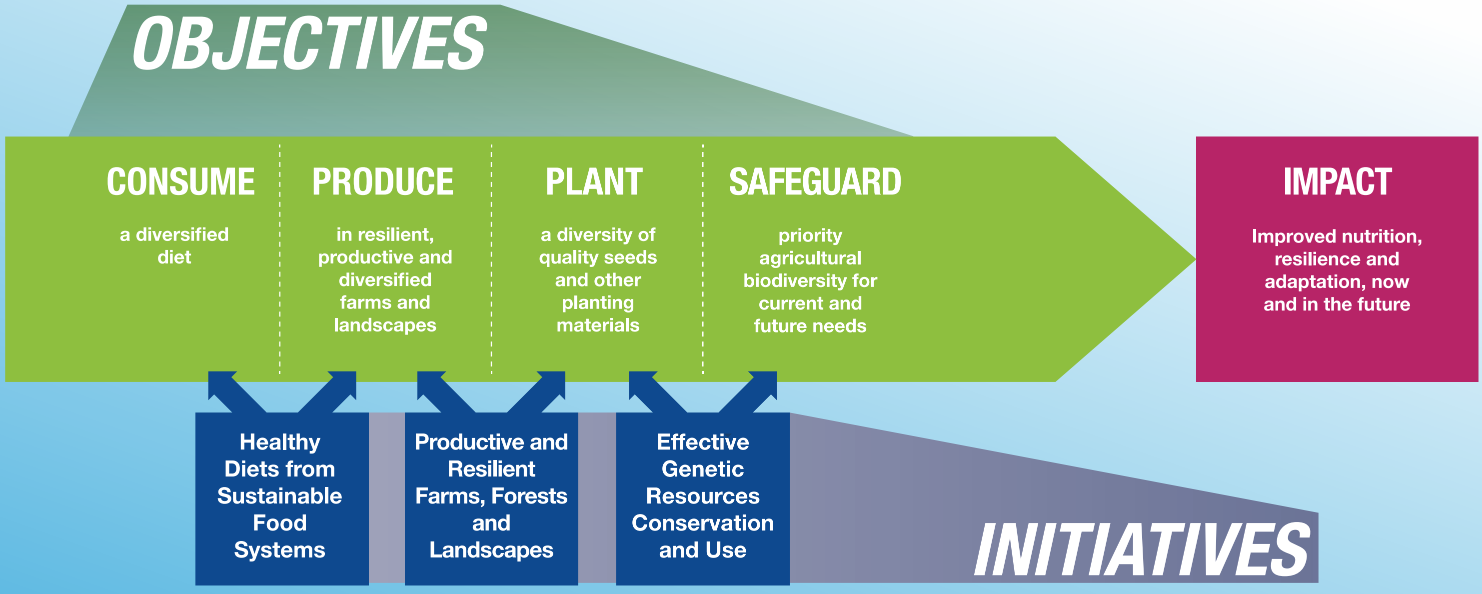
The recognition of the roles of agricultural biodiversity in smallholder farmers' livelihood strategies has taken on even greater salience as the world looks for sustainable solutions that produce food that is more nutritious without creating negative environmental impacts. Our research now combines modern science with farmer knowledge to understand how best to use biodiversity in production systems that are resilient, sustainable, low input, and that support the well-being and autonomy of rural communities. Important areas of focus are production systems based on banana cultivation, priority tree species that communities depend on, sustainable farming systems, the interactions between gender and biodiversity conservation and use, and neglected and underused species and varieties.

Consume (2006–present)

From our research on the value of agricultural biodiversity to farmers in traditional systems such as home gardens, it was becoming clear that food biodiversity underpins dietary diversity, which in turn promotes good nutrition. In the early 2000s, the World Health Organization announced that non-communicable diseases, such as cardiovascular conditions and diabetes, had overtaken communicable diseases as the main cause of death, and launched a major endeavour to tackle that through better diets. Cereals and starchy crops were at the heart of the Green Revolution, but many vegetables, nuts, fruits and small grains needed to provide a healthy, diverse diet had been neglected by research and markets. That needed to change, because access to a wide variety of food groups is crucial to a healthy and sustainable diet, and local species represent a basket of easily available options.

In 2006, we adopted our new name Bioversity International, and the Convention on Biological Diversity asked us together with FAO to jointly take the lead on developing the evidence base for a cross-cutting initiative on biodiversity for food and nutrition. Research so far indicates that many local plant species and varieties, including many food trees, are nutrient rich and only require low inputs, so could make a greater contribution to good diets and improved nutrition. Our research agenda looks at the whole plate as well as individual ingredients.

We explore the contributions that food biodiversity, supplied by integrated farming systems, can provide to sustainable diets in rural and urban areas. We work in a gender-sensitive way to bring back local food biodiversity to improve nutrition and livelihoods.



Today's strategic priorities

Increasing the sustainable use of agricultural and tree biodiversity in production and consumption systems plays an important part in solving today's challenges – reduce global malnutrition, adapt to climate change, increase productivity and reduce risk, and address shrinking food diversity.

Bioversity International's strategic objectives are to diversify diets, production systems, seeds and planting material, and safeguard biodiversity.

To achieve these objectives, Bioversity International integrates its research portfolio into three initiatives.

1974
CGIAR sets up the International Board for Plant Genetic Resources (IBPGR), a major effort to collect genetic resources, hosted at the Food and Agriculture Organization of the UN (FAO)

1980
Supporting its collecting effort, IBPGR starts researching conservation methods to ensure that the collected materials would be safeguarded effectively

1983
The International Undertaking is adopted by the state members of the Commission on Plant Genetic Resources. Under this non legally binding agreement, states agree that plant genetic resources are a heritage of [hu]mankind and not subject to restrictions

1985
IBPGR becomes a CGIAR Centre

1985
The International Network for the Improvement of Banana and Plantain (INIBAP) is created to address the threat of new disease epidemics

1985
IBPGR scientists start discussing the idea of a ‘backup storage’ in the Svalbard permafrost to ensure a permanent backup of all major crop collections

1987
IBPGR becomes fully autonomous from FAO

1987
New IBPGR strategy starts strengthening links between conservation and use of plant diversity

1992
IBPGR represents CGIAR at the Rio Earth Summit

1992
The UN Convention on Biological Diversity is signed by 150 government leaders at the 1992 Rio Earth Summit

1993
IBPGR becomes the International Plant Genetic Resources Institute (IPGRI)

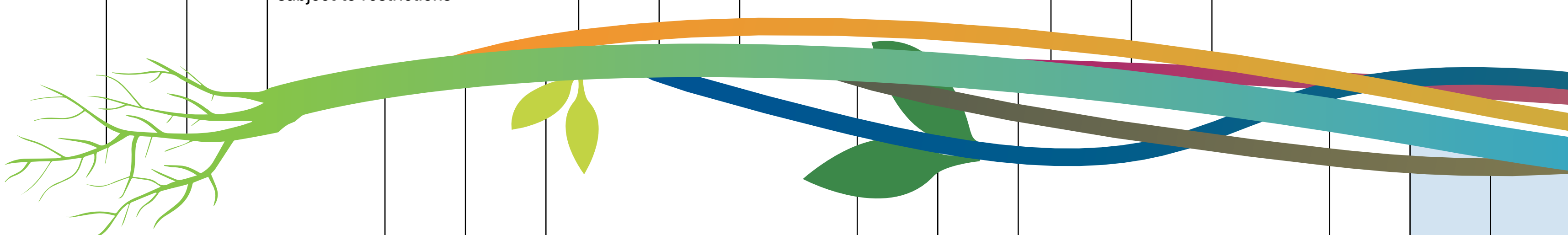
1993
IPGRI launches a new strategy, with a focus on people: ethnobotany, traditional knowledge and on-farm management systems

1994
IPGRI merges with INIBAP

1994
The System-wide Genetic Resource Programme is set up, coordinated by IPGRI, to harmonize approaches to managing genetic resources across CGIAR, and the CGIAR collections are put in trust under the auspices of FAO

1995
FAO launches the first *State of the World’s Plant Genetic Resources for Food and Agriculture* with substantial technical support from IPGRI

1996
The International Technical Conference on Plant Genetic Resources ratifies a global plan of action for the better conservation and use of plant genetic resources important for food and agriculture, based on the *State of the World Report*



2000–2015
Millennium Development Goals

2002
IPGRI and FAO found the Crop Trust, an endowment fund to provide stable funding to the world’s major genebanks

2002
IPGRI represents CGIAR at the Earth Summit, Johannesburg

2004
Negotiations completed for the International Treaty on Plant Genetic Resources for Food and Agriculture with important contributions from IPGRI on behalf of the major genebanks

2006
INIBAP and IPGRI begin working under the name Bioversity International, reflecting an expansion from plant genetic resources only, to agricultural biodiversity from gene to landscape level

2006
Bioversity and FAO invited to lead the 'Biodiversity for Food and Nutrition' cross-cutting initiative launched at the Convention on Biological Diversity 8th Conference of the Parties

2009
Bioversity launches a new approach 'Seeds for Needs' to help farmers adapt to climate change

2010
FAO launches the second *State of the World's Plant Genetic Resources for Food and Agriculture*, with significant technical support from Bioversity

2012
Bioversity scientists contribute to an international effort on sequencing one of the founding genomes of banana

2012
Bioversity and FAO launch *Sustainable Diets and Biodiversity: Directions and Solution for Policy, Research and Action*, an important initiative towards diets which are healthy for people and protective of the environment

2014
FAO launches the first ever *State of the World's Forest Genetic Resources* and the *Global Plan of Action* with strong inputs from Bioversity scientists

2015–2030
Sustainable Development Goals

2015
Refreshed strategy with three new research initiatives: Healthy diets from sustainable food systems; Productive and resilient farms and forests; Effective genetic resources conservation and use

2015
Paris Agreement on Climate Change

2016
Bioversity launches the concept for an Agrobiodiversity Index, a tool to measure agrobiodiversity and identify concrete actions to achieve diverse and sustainable food systems

2017
Bioversity launches the flagship publication *Mainstreaming Agrobiodiversity in Sustainable Food Systems*. The book summarizes the most recent evidence on how to use agrobiodiversity to provide nutritious foods through harnessing natural processes

2018
Bioversity forms an Alliance with the International Centre for Tropical Agriculture (CIAT)

Our research on bananas

165 million tonnes of bananas (*Musa* spp.) are produced a year in over 130 countries. They are an important staple food crop for 400 million people and an essential source of income for thousands of rural households in low-income countries. Bananas include cooked and dessert types and comprise numerous 'subgroups' such as plantains. There are thought to be nearly 80 wild banana species and more than 1,000 varieties worldwide.

Banana-related research at Bioversity International began in 1985, when the International Network for the Improvement of Banana and Plantain (INIBAP) was founded. It was established to promote the conservation and safe exchange of genetic resources in support of banana improvement, largely in response to the threat of the emerging disease Black leaf streak (black Sigatoka). Unlike other international agricultural research centres, it took a novel network approach. In 1991, INIBAP became a CGIAR centre and in 1994, a programme of Bioversity International (as IPGRI – the International Plant Genetic Resources Institute). In 2006, INIBAP and IPGRI joined forces and adopted the name Bioversity International. Since 2012, Bioversity's banana group has been a partner of the CGIAR Research Program on Roots, Tubers and Bananas.

The banana programme organized research through working groups and four regional networks. The initial focus was on the safe movement of banana germplasm, breeding, disease management and conservation. Later this expanded to include banana production and processing, genomics and bioinformatics.

Edible bananas are seedless and therefore require unique conditions for their *ex situ* conservation. The Bioversity International *Musa* Germplasm Transit Centre (ITC) was established in 1985 at KU Leuven, Belgium, where it now conserves over 1,550 banana accessions from 37 countries in an *in vitro* collection. Over 1,000 of these accessions are conserved in perpetuity via cryopreservation. The ITC also serves as a safety backup for national genebanks and ensures that germplasm is clean of pests

and diseases and freely available under an agreement set by the International Treaty on Plant Genetic Resources for Food and Agriculture.

A significant milestone occurred in 2012, when Bioversity was involved in the first ever sequencing of the banana whole reference genome, which has led to the discovery of important links between genetics and desirable traits. Big data tools and electronic communication have also opened new opportunities for regional collaboration in banana mapping, climate change readiness, cultivar testing, more efficient germplasm conservation, research priority setting and collaborative projects.

In 2016, following a 2-year consultation with over 100 stakeholders, Bioversity updated the Global Strategy for the Conservation and Use of *Musa* Genetic Resources (first launched in 2006), a core reference and roadmap for the banana community for the next ten years. MusaNet, the global banana genetic resources network coordinated by Bioversity, has a mandate to further develop and implement the strategy.

To disseminate the fruits of its research, Bioversity builds capacity in the banana-producing regions, for example MusaNet workshops on characterization and documentation in all the banana network regions, while bi-annual symposia on production-related topics are coordinated by ProMusa, Bioversity's banana knowledge-sharing platform.

The founders of INIBAP back in 1985 may not have realized that their proposal for a banana network would provide such wide-reaching inspiration so many years later.

Rachel Chase

2013–today: Research Assistant, *Musa* Genetic Resources Team

Our research on trees

Bioversity International is the only global organization that carries out research for development oriented towards conserving the diversity within and among populations of wild trees, with an eye to sustaining their populations in the wild.* Trees in natural forests and woodlands are vital to rural people living in low-income countries, who obtain from them: construction materials, food such as fruits, nuts, honey and edible caterpillars; fuel to cook their food; and medicines. And whereas the major food crops (maize, wheat, rice) are grown across all the continents, people in different regions depend on thousands of different tree species that grow locally, which vary from one region to another.

The diversity within these wild trees contributes to their capacity to adapt to different environmental conditions, from drought to flooding, and resist pests and diseases; as well as defining the seasonality, nutritional values, flavours and characteristics of their fruits. Bioversity has focused on conserving the diversity within populations of the 100 or so tree species that are considered by local representatives to be most important in different regions around the world, from Central Asia to Africa, Asia and Latin America. It is a daunting task. Whereas a sample of a wheat population can be conserved in a small aluminium envelope in a freezer, conserving a sample of a tree population requires thousands of hectares of forest. Why? First, because most tree seeds from the tropics lack dormancy, so they can't be stored – seeds either germinate right away or they die; and second, because trees don't breed true. Each seed is genetically different from its parent tree.

Bioversity launched its programme on the conservation and use of the genetic diversity of trees in 1993, under the leadership of Abdou Salam Ouedraogo. A major research area has been setting priorities for research among the nearly 80,000 species of trees. Priority-setting considers their value to rural people, the distribution of within-species diversity among their populations and the threats to those wild populations. Another major field of research has been methods for conservation, both *in situ*, including setting aside protected areas and management of wild populations in utilized forests or woodlands; and *ex situ*, based on tree seedbanks, field genebanks and botanical gardens as well as *in vitro* and cryopreservation.

Bioversity established networks of experts and decision-makers from countries within each region to help them prioritize among species and implement

*Our fellow scientists and frequent collaborators at the World Agroforestry Centre (ICRAF) also carry out research on tree genetic resources, with an eye to their domestication and planting on farms.

research and policy initiatives through forest genetic resource networks: first in Europe (EUFORGEN); then in sub-Saharan Africa (SAFORGEN); Asia Pacific (APFORGEN) and Latin America (LAFORGEN). Bioversity researchers collaborated closely with the Food and Agriculture Organization of the UN (FAO) to develop and promote policy tools for the conservation and better use of the genetic diversity of trees, playing a key role in developing the first report on the *State of the World's Forest Genetic Resources* and the associated *Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources*, both released in 2014. In this undertaking, as well as the CGIAR Research Program on Forests, Trees and Agroforestry (FTA), launched in 2010, Bioversity collaborated closely with fellow CGIAR scientists at the World Agroforestry Centre. Through FTA, Bioversity has also worked in collaboration with the Center for International Forestry Research (CIFOR) and with the Tropical Agricultural Research and Higher Education Center (CATIE), and with national partners in research centres, government agencies and universities in countries around the world.

A major focus of Bioversity's forest genetic research in recent years has been forest landscape restoration: identifying sources of high-value reproductive material and promoting their conservation, while developing and providing tools and approaches to ensure that tree seeds collected and planted are obtained and managed to ensure sufficient genetic diversity. This is needed so that restored forests can regenerate naturally, adapting, from one generation to another, to changes in climate and other environmental conditions.

Laura K. Snook

2018–today: Honorary Research Fellow

2015–2018: Research Team Leader, Forest Management and Restoration

2012–2015: Programme Leader, Forest Genetic Resources Conservation and Sustainable Use

2005–2012: Programme Director, Understanding and Managing Biodiversity

Our work on neglected and underutilized species

Can species that are locally important be deployed more widely in national, regional and global agriculture? Are there uses of local crops that can be improved so that people benefit more? How does the neglect of locally important crops threaten their genetic base? And conversely, what positive impacts might emerge if we increase use of their genetic diversity and associated knowledge?

In 1994, these key research questions led to the Underutilized Mediterranean Species project, focusing on four key crops: rocket, oregano, pistachio and hulled wheats (einkorn, spelt and emmer). This project was funded by Italy and led by Bioversity International (as IPGRI – the International Plant Genetic Resources Institute) with multi-country collaborative networks.

Unsustainable harvesting was posing a high threat to rocket genetic resources in the wild. The research showed how emerging technologies (e.g. soilless cultivation and packaging for ready-to-eat vegetables) along with domesticating wild species could improve the use, conservation and consumption of rocket. Today rocket is a commodity crop around the world, in part thanks to our work popularizing it and finding ways to grow it sustainably.

Einkorn (the now well-loved 'farro'), a once-popular crop, by the mid-1990s had become a relic crop, cultivated in very few sites. Our research helped bring it back to the table. Our efforts on oregano and pistachio showed how even popular crops needed additional support for smallholder farmers to benefit from marketing these crops in the Mediterranean and elsewhere.

In 1996, Bioversity played a major role in getting a specific action on underutilized species included in the *Global Plan of Action for Plant Genetic Resources for Food and Agriculture* by the Food and Agriculture Organization of the UN (FAO). This was an important step to raise awareness about the value of these species among decision-makers around the world.

The Underutilized Mediterranean Species project ended in 1998, paving the way for a new global endeavour on neglected and underutilized species (NUS). Highly innovative, the NUS programme has now been active for almost two decades. It takes an interdisciplinary, inter-sectorial, participatory and bottom-up approach

to mobilize NUS in order to fight food and nutrition insecurity, poverty, climate change and the marginalization of disadvantaged groups like women and indigenous peoples.

The International Fund for Agricultural Development (IFAD) NUS Programme has worked globally, but through a country focus (Ecuador, Bolivia, Peru, Yemen, Egypt, Nepal, India, Mali and Guatemala) and a crop-by-crop approach (Andean grains, minor millets, chaya, fonio, Bambara groundnut and jute mallow).

In these two decades of work, Bioversity has contributed to bringing individual crops back from oblivion: rocket in Italy, quinoa in Bolivia, leafy vegetables in Africa south of the Sahara, and minor millets in India. Opening up markets for these nutrient-dense and locally adapted crops has increased incomes for smallholder farmers, boosted diversity in fields and home gardens, raised yields and improved diversity in diets. But perhaps the most important message of all is the immense potential of NUS that are still unexploited. Of the 1,097 plants now recognized as vegetables, only a fraction are well known and commercialized. Which will be tomorrow's rocket?

Stefano Padulosi

2018–today: Research Team Leader, Rural Urban Agri-food Systems, Healthy Diets from Sustainable Food Systems Initiative

2001–today: Coordinator, IFAD NUS Programme and NUS focal point

1998–2004: Coordinator Central, West Asia and North Africa Regional Project

1993–1998: Coordinator, Underutilized Mediterranean Species Project

Bioversity International and CGIAR

In 1971, there was widespread concern that rapid increases in human populations would soon lead to widespread famine. The Mexico-Rockefeller Foundation International Agriculture Program, established in 1943 to increase agricultural production, primarily of beans, maize, wheat, potatoes and rice, had proposed the creation of a worldwide network of agricultural Research Centres under a permanent secretariat. The World Bank, the Food and Agriculture Organization of the UN, and the UN Development Programme, supported this idea.

CGIAR's mandate was to "reduce poverty and achieve food security in developing countries." At this time CGIAR was a rather loose framework for dialogue among donor members about research priorities, investment options, and the continuing relevance and effectiveness of the institutions it supported. Its early mission was to generate high-yielding crop varieties through plant breeding, a focus that remains strong today. Yet at the same time, the increase of modern high-yielding varieties were putting at risk traditional farmers' varieties – in other words, the genetic diversity on which these breeders depend.

In response, just three years later in 1974, there was a groundbreaking agenda item at the CGIAR Subcommittee on Genetic Resources meeting – to establish the International Board for Plant Genetic Resources (IBPGR).

IBPGR's mandate was to "identify general and specific needs for exploration, collection, conservation and evaluation of plant genetic resources with particular reference to species of major economic importance and their wild and cultivated relatives, to determine priorities among them, and to ensure that the materials conserved are made available for plant breeding and other scientific activities as required." IBPGR set out on a race against time to collect and secure as much genetic diversity as possible of priority crops (primarily major food crops).

In 1985, IBPGR became a freestanding CGIAR Research Centre with a broadened mandate to conduct research as well as provide services.

The close relationship between Bioversity International and CGIAR continues to this day, with both entities adapting and evolving in response to the changing authorizing environment along the way. For example, in 1985, CGIAR broadened focus to consider how food production affected the natural resource base, around the same time that IBPGR (now operating as IPGRI – the International Plant Genetic Resources Institute) widened its own scope to look at strengthening the interface between germplasm conservation and its use.

There are many highlights along the way, many of which are included in this book, such as:

- How and why, in 1994, IPGRI merged with the International Network for the Improvement of Banana and

Plantain (INIBAP), which was also part of the CGIAR Network.

- The role of Bioversity International as coordinator of the CGIAR System-wide Genetic Resources Programme (SGRP). This initiative was to foster close collaboration among the CGIAR Research Centres. It was established in 1994 in response to the Convention on Biological Diversity and FAO's *Global Plan of Action for Plant Genetic Resources for Food and Agriculture*. Through SGRP, IPGRI represented genetic resources both within and externally to CGIAR, and enabled CGIAR to speak with 'one voice', for example, at the Convention on Biological Diversity. The ultimate form of the International Treaty on Plant Genetic Resources for Food and Agriculture owes a lot to SGRP, recognized in 2006 by the CGIAR Partnership Award.

- The creation of the Crop Trust which began life through the CGIAR Finance Committee in 2000 who endorsed our suggestion to create an endowment fund to stabilize funding for national and CGIAR genebank collections. Initially set up by IPGRI (representing CGIAR) and FAO, today the Crop Trust operates as an independent entity, with a mandate to ensure the conservation and availability of crop diversity for food security worldwide.

That is not to say it has all been plain sailing. A bit like in any long-standing marriage, there have been both good times and difficult ones. Changes in CGIAR funding streams, structures and research priorities have not always aligned favourably to our own evolving vision and mission. The funding environment also remains challenging.

The upside to the above trends is that it compelled us towards greater clarity on our contribution to the global challenges of malnutrition, land restoration, sustainable intensification and climate change resilience using agricultural and tree biodiversity, while ensuring the conservation of diversity on the ground for future use. Another shift is the recognition that solutions identified through research need to achieve impact at scale. We have always worked in close partnership at the national level – this new reality now necessitates new partnerships both upstream with universities as well as downstream with development partners.

As we look ahead to the next exciting step of our Alliance with another CGIAR Centre, the International Center for Tropical Agriculture, we are pleased to see recent forward momentum in CGIAR's agenda to drive transformation in food systems so that they work for people and the planet. We look forward to our continued collaboration with CGIAR in the years ahead.

CGIAR is a global research partnership for a food-secure future. Its science is carried out by 15 research centres in close collaboration with hundreds of partners across the globe. Its mission is to reduce poverty; improve food and nutrition security; and improve natural resources and ecosystem services. CGIAR Research Programs are supported by contributors to the CGIAR Trust Fund. https://www.cgiar.org/funders/

"CGIAR is working towards improving system performance. We will take bold steps forward to deliver high quality research through a commitment to partnership, transparency and accountability."

Ann Tutwiler, Director General, Bioversity International, and CGIAR System Management Board member (July 2016-August 2018)

Stephan Weise

2011–today: Deputy Director General, Research

2008–2011: Director of the Commodities for Livelihoods Programme

"The establishment of IBPGR illustrated the importance the CGIAR attached to genetic resources and their conservation globally. IBPGR and its successors, the International Plant Genetic Resources Institute (IPGRI) and then Bioversity International, would play important roles globally in helping developing countries address genetic resource conservation and related intellectual property issues."

from The CGIAR at 40

Bioversity International and Italy

Bioversity International is proud of its strong links with Italy – a country with a rich agricultural biodiversity heritage. UNESCO has inscribed its internationally renowned food culture as an Intangible Cultural Heritage of Humanity.* It is recognized as a global leader in sustainable food and agricultural systems, a reputation cemented as host of EXPO 2015 Feeding the Planet, Energy for Life and of the Global Food Innovation Summit Seeds&Chips. In 2020, Italy will host the 2nd International Agrobiodiversity Congress.

Our Headquarters have remained in Rome since we first opened our doors as the International Board of Plant Genetic Resources in 1974. Originally we were established by CGIAR (then called the Consultative Group on International Agricultural Research), administered by and located in the Food and Agriculture Organization of the UN (FAO). FAO is still located here in Rome along with the World Food Programme and the International Fund for Agricultural Development – international organizations with whom we work closely. In 1991, we became an independent organization, signing a Headquarters Agreement with the Italian Republic. Today, fittingly, our offices are in a converted grain mill in an agriculturally important area on the edge of the city.

In 2016, the Italian Parliament ratified the hosting agreement between the Government of Italy and Bioversity International, further strengthening the relationship. This agreement reinforces our commitment to advance research activities, scalable solutions and innovations to use and safeguard agricultural biodiversity to nourish people and sustain the planet and contribute to the achievement of the Sustainable Development Goals.

*UNESCO inscribed the Mediterranean Diet of Cyprus, Croatia, Greece, Italy, Morocco, Portugal and Spain under the Convention for the Safeguarding of Intangible Cultural Heritage of Humanity in 2013.

Italy provides generous financial support to Bioversity International's mission that addresses key global challenges including mainstreaming agrobiodiversity in sustainable food systems for rural development, resilient food systems, nutritional security and climate change adaptation.

In particular, we are focusing on how this work can contribute to social and economic stability, for example, by generating new market opportunities for farmers, contributing to job creation and livelihood opportunities specifically for women and youth as well as helping to prevent migration.

The fruitful collaboration between Italy and Bioversity International continues to go from strength to strength through continuous knowledge exchange, policy dialogue and joint research initiatives with the Ministry of Foreign Affairs, the Italian Agency for Development Cooperation, and Italian scientific research institutes and universities, and agricultural and sustainable development policy institutions.

Richard China

2014–today: Director, Strategic Partnerships and External Engagement

Staff

Meet Our Staff: Evelyn Clancy, Josephine Luzon and Dario Valori

Evelyn Clancy

1990–today: Programme Assistant

Longest-serving staff member

What I appreciate about Bioversity International is our dedication to work with men and women farmers and farming communities to manage agricultural biodiversity and to increase access to and availability of seeds which contributes to food sovereignty and security.

Our work on enabling policy environments to overcome challenges such as climate change, inspired me to study sociology and environmental policy to play my part in supporting our mission.

Josephine Luzon

1993–today: Finance Manager

I am always proud to say I was Bioversity International's first employee. The first employment contract issued by the (then) International Plant Genetic Resources Institute (IPGRI) as an autonomous CGIAR centre, was mine, to lure me out of my fantastic job with the US State Department at the American Embassy here in Rome.

Even after 26 years of service, every day is like the first day of work with Bioversity. Every day is different – challenging and exciting. I am passionate about Bioversity's mission. I am proud to be a part of something grand and achievable in making our world a better place to live in, and I see all of us together making strides day by day and making the vision a reality.

Each and every one of the Bioversity staff in their own way have the 'X factor'. I love all my colleagues – outstanding professionals and uber-awesome human beings.

Buon anniversario, Bioversity International!

Dario Valori

1998–today: Information Technology Manager

When I started 21 years ago, Bioversity International (as IPGRI – the International Plant Genetic Resources Institute) was growing 10% per year and a leader in its niche. There was a lot to be proud of and our commitment was on a par with our dreams of what we were doing to help people. We have been through a lot since then as changes have occurred and the organization has matured. But I still appreciate providing services to an organization that has always been quoted as top notch by its staff.

SAFEGUARD

Collecting in the 1980s: first forays in Africa

As people began to appreciate the threat that genetic erosion posed, countries began to collect landraces and farmers' varieties to conserve them in genebanks. I had just completed the graduate genetic resources course at the University of Birmingham, England, in 1975. Along with a few others, I became one of the first plant genetic resource collectors working for Bioversity International (as IBPGR – the International Board for Plant Genetic Resources).

In Ethiopia, in 1980 and 1981, I was collecting with two local experts for the newly established Genetic Resources Centre in Addis Ababa. Our focus was farmer varieties of the main food crops. We travelled into the countryside as best as we could, along the main roads. People later criticized that, saying we weren't getting an accurate sample of the local agricultural biodiversity. But actually, that is how the modern new varieties were spreading, along the main roads, and so that is where genetic erosion was most advanced and where we needed to collect most urgently. Our aim in the 1980s was not so much to collect a representative sample of all available genetic diversity as to save varieties that were being replaced. In any case, at that time most of the country wasn't accessible, either physically or politically.

Collecting would take place at harvest time. We would meet farmers at work in their fields and after asking their permission, my colleagues would talk to the farmers about what they called their varieties and what were the most important characteristics. I wrote down the answers and observations about the site, such as the soil type and the other crops. Then the three of us crossed the field to take a random sample of seeds that went into a cotton bag for processing into storage at the genebank in Addis Ababa.

In 1982, Zimbabwe had recently achieved independence and wanted to conserve varieties from non-commercial farmers. Local experts and I collected from farmers and in local markets. Unlike in Ethiopia, the resources collected were shared between Zimbabwe and IBPGR-designated genebanks, which had been given responsibility as the base collections for particular crops. Squashes and pumpkins, for example, went into the genebank system of the US Department of Agriculture. In Burundi, in 1985, we were collecting to help create a regional

genebank for Burundi, Rwanda and eastern Zaire (now Congo), and the beans we gathered were safely duplicated in the international collection at the International Center for Tropical Agriculture (CIAT), a CGIAR research centre.

IBPGR was crucial in setting priorities, providing guidance and promoting the collaboration needed for these early collecting and conservation efforts, in addition to giving financial support. IBPGR set up crop advisory committees that brought together the most learned experts knowledgeable in the diversity of each species and its state of conservation and use. It produced a range of technical guidelines on collecting, conservation and documentation as well as training programmes and aids.

Jane Toll

2007–2014: Senior Project Manager, Crop Trust
2005–2007: Director, Global Partnerships Programme, Crop Trust
1995–2007: Coordinator, CGIAR System-wide Genetic Resources Programme
1992–1995: Senior Scientist, Germplasm management
1987–1992: Coordinator, West Africa, Niamey, Niger
1985–1987: IBPGR Officer, Great Lakes Region (Burundi, Rwanda and Zaire (DR Congo))
1980–1985: IBPGR Collector and Consultant

The Collecting Missions Database (http://bioversity.github.io/geosite/) provides access to the original passport data of more than 220,000 samples collected around the world over almost 40 years during Bioversity International-supported missions. About 150,000 samples are currently geo-referenced. You can also access over 3,200 original scanned field reports at the Collecting Missions File Repository (http://www.central-repository.cgiar.org/crop_collecting_missions.html).

Collecting today: wild relatives of bananas

In 2016, the Crop Trust funded a banana collecting mission to Papua New Guinea. Missions in the late 1980s, led by Suzanne Sharrock, collected 264 wild and cultivated samples, of which 86% were original types not found anywhere else. These samples are still conserved *in vitro* in the Bioversity International *Musa* Germplasm Transit Centre (ITC) in Belgium and have been widely used in research studies. The 1980s missions had, however, missed the Autonomous Region of Bougainville, at the time, a site of civil conflict. Could this region contain even more valuable banana diversity? Given the high diversity already collected in Papua New Guinea, I feared that we could not collect many more new banana varieties. But I was happy to be proved wrong.

The expedition to Bougainville, co-organized with our partners from the Papua New Guinea National Agricultural Research Institute, resulted in the collection of 61 samples most of which seemed new to expert eyes. Thanks to the *Musa* Genotyping Centre hosted in the Institute of Experimental Botany in Olomouc, Czech Republic, we were able to genotype the samples collected and we confirmed 35 new genotypes, which is a lot for a clonal crop like banana. We also got a better understanding of the dynamics behind banana diversification on farm. For example, we found two varieties with the exact same genotype but differing highly in appearance: Tambra is variegated while Morou is not. Clearly, farmers had captured and conserved a natural mutant that occurred in their fields. But the main lesson we learned from the collecting mission to Bougainville is that, even though the Pacific region has been extensively explored already, there is still a lot of undescribed diversity out there. In fact, we will be back to the Pacific on new banana collecting missions (funded by the Crop Trust) in 2019.

One brand new aspect we explored, together with the Botanic Garden of Meise (Belgium) in this mission and a second one on the Papua New Guinea main island in 2017, was to conduct molecular genetic studies on the wild species we collected. For the first time, massive sampling of wild banana populations was performed, which included hundreds of dried leaves and seeds. This will allow us to analyze the genetic diversity of wild banana species at the population

level, which will considerably increase our knowledge of wild banana biology and therefore the efficiency of their conservation. Beyond the obvious aspect of safeguarding this precious and endangered biodiversity, this work will also open a new era for the use of banana wild relatives, notably in research for breeding.

Julie Sardos

2017–today: Scientist, *Musa* Genetic Resources

2012–2016: Associate Scientist

"Collaborative projects like this have greatly contributed towards collecting, conserving and maintaining Papua New Guinea's second most important food crop for current and future generations. The materials have been safely duplicated and conserved at the Bioversity International Musa Germplasm Transit Centre in Belgium, and we have broadened our scientific knowledge and skills on Musa diversity in Papua New Guinea. The scientific knowledge gained will be imparted to our upcoming national Musa scientists to effectively contribute towards Musa research both nationally and internationally."

Janet Paofa
Plant Curator (Food crop) Papua New Guinea National Agricultural Research Institute

How to store seeds long term

Seeds, unfortunately, do not last forever. If genebanks are to store them effectively, they need to know the best conditions to keep them in. Research into seed storage was one of the first activities undertaken by Bioversity International (as IBPGR – the International Board for Plant Genetic Resources) and continues today.

Having helped GIZ (the German development agency) to set up regional genebanks in Costa Rica and Ethiopia, I joined IBPGR, having trained as a plant breeder in the early 1970s in Wageningen. I had realized that plant breeders' work can threaten diversity so I moved to the camp fighting to maintain it.

Working closely with a research group at the University of Reading in the UK, we established protocols to measure the viability and longevity of seeds. This meant that we could see how different conditions affected the length of time for which seeds could be stored without too many of them dying and thus, not losing the genetic identity of the accessions. We found that seeds lasted longest when they were dried well and kept cold, and the Reading researchers established a rule of thumb that seeds should be dried to about 5% moisture and kept at -18°C.

That coincided with the temperature in a chest freezer, which implied a fairly low-tech and simple way for countries to maintain their seeds long term. IBPGR supported countries around the world to build genebanks equipped with drying chambers and freezers. We recommended that seeds were sealed in aluminium foil pouches to keep them dry even if they did warm up for a short period. Better equipped genebanks had standby generators to keep their freezers running in the event of power cuts.

However, power cuts are a fact of life in many lower-income countries. This was one factor that led in the 1990s to Bioversity International (now operating as IPGRI – the International Plant Genetic Resources Institute) exploring an 'ultra-dry' seed storage approach. This meant drying the seeds down to a very low level so they could be stored in hermetically sealed pouches at room temperature for acceptable seed longevity. Results were mixed however: some researchers feared that overdrying the seeds could decrease

longevity. To understand long-term seed storage options better, we started a global seed project. Our researchers, working with colleagues in China, India and the USA, established that each species had a different optimum level of dryness for any given storage temperature.

Our research on seed storage proved crucial to the growth of the genebanks established to conserve agricultural biodiversity and the results provided the basis for many of the genebank standards that we published with the Food and Agriculture Organization of the UN (FAO) in the early 1990s. A few revisions later, these are still a valuable resource today.

Jan Engels

- 2012–today: Honorary Research Fellow
- 2010–2015: Coordinator, CacaoNet
- 2008–2016 Coordinator, European Genebank Integrated System (AEGIS)
- 2005–2011: Genetic Resource Management Advisor, including acting Director of the International Network for the Improvement of Banana and Plantain (INIBAP)
- 1995–2005: Director, Genetic Resources Science and Technology Group
- 1992–1995: Group Director, Germplasm Maintenance and Use
- 1988–1991: Coordinator for South and Southeast Asia, New Delhi

The world's largest banana genebank

The Bioversity International *Musa* Germplasm Transit Centre (ITC) is home to the world's largest collection of banana diversity. Its mission? To contribute to the secure, long-term conservation of the entire banana genepool and hold the collection in trust for the benefit of current and future generations under the auspices of the Food and Agriculture Organization of the UN.

Founded in 1985, the ITC is managed by Bioversity International and hosted at KU Leuven, Belgium. The collection contains more than 1,500 accessions of edible and wild species of banana, and continues to grow as new specimens are collected in Southeast Asia, and East and West Africa, centres of banana diversity.

Banana does not reproduce through seeds; new plants grow from young shoots that arise from the parent plant. This is why in genebanks, bananas are conserved in the field, as small plantlets *in vitro* (in test tubes) or put into long-term cryopreservation. At the ITC, the collection is maintained *in vitro* under slow growth conditions at 16°C or cryopreserved at -196 °C. For material to be exchanged, it needs to be free of pests and pathogens including fungi, bacteria and viruses. The ITC tests its materials and distributes only those free of pests and pathogens.

Obtaining material from the ITC is easy. Samples are available upon request on the *Musa* Germplasm Information System (MGIS) portal, through the Multilateral System of Access and Benefit Sharing of the International Treaty on Plant Genetic Resources for Food and Agriculture. In more than 30 years of activity, the ITC has distributed over 18,000 banana samples to researchers and farmers in 110 countries. On average, 75% of the samples go to users in the main banana-growing regions – Africa (27%), the Americas (25%) and Asia and Pacific (23%) with the remainder sent to universities and research centres in Europe.

In addition to conservation, Bioversity uses the genebank to carry out research to benefit farming communities worldwide. When our Nutrition team was looking for vitamin A-rich bananas to improve diets

in East Africa, they worked with the ITC to identify 400 varieties with high levels of carotenoids to use in their research. When our Banana Disease team was seeking banana cultivars resistant to the deadly disease Fusarium wilt (also known as 'Panama disease'), the ITC helped to send samples of East African Highland Bananas to infected areas in China and the Philippines, to see how they would react to the virulent fungal strain.

Exploiting banana's genetic diversity to find drought-tolerant varieties and traits is an important strategy in a context of global water scarcity. Through phenotyping — the science that characterizes and quantifies complex plant features such as growth, yield and stress tolerance — Bioversity and KU Leuven are studying the drought tolerance of banana varieties in the collection. Drought-tolerant varieties will be tested in farmers' fields, helping production systems to be more resilient. A better understanding of the genetic traits will accelerate breeding for new drought-tolerant varieties.

Ines Van den houwe

2014–today: ITC *Musa* Collection Curator, Bioversity International

1994–2013: Scientific Collaborator, *In Vitro* Conservation, KU Leuven

Freezing time: preserving plant genetic resources forever

Cryopreservation means the storage of biological material in liquid nitrogen at -196°C. This temperature is low enough to arrest all metabolic and physical processes, enabling the material to be kept safely for hundreds of years.

For different reasons, cryopreservation plays an essential role in the safe conservation of crops like bananas, cassava, potato, yams, sweet potato, coconut and many fruit trees, because in each case seed preservation at -20°C, the most convenient method to store plant germplasm, is not an option. Bananas, for example, are sterile, and do not produce viable seeds. Cocoa and coconut produce only recalcitrant seeds that die if they are dried. Potato and many fruit species do not breed true from seed, and so cryopreservation of plant tissue is needed to conserve the specific gene combinations that constitute a known variety.

Cryopreservation research on bananas started in 1984 at KU Leuven, which hosts the Bioversity International *Musa* Germplasm Transit Centre (ITC), under the guidance of Edmond de Langhe, one of the founding fathers of the International Network for the Improvement of Banana and Plantain (INIBAP) and the institute's first director. That year, de Langhe announced an MSc thesis subject — cryopreservation of banana meristems — which looked very appealing to me. At that time plant cryopreservation was considered a futuristic and exciting research subject. Lyndsey Withers, a pioneer of plant cryopreservation who was working for Bioversity International (as IBPGR – the International Board for Plant Genetic Resources) was promoting cryopreservation as the method of choice for the long-term conservation of vegetatively propagated plants. In view of where we are now, how visionary both Lyndsey and Edmond were.

In the following years, different cryopreservation techniques were developed and optimized in the framework of different MSc and PhD theses and research projects, but it was not until colleagues and I developed the droplet vitrification protocol in 2003 that routine cryopreservation of the banana collection could take place. Vitrification is the process to prevent ice crystal formation during low temperature exposure that would otherwise damage the cells. Our protocol greatly increased the success rate for regenerating whole plants from frozen tissues.

Since then, 1,117 *Musa* accessions (of the 1,566 accessions available at the ITC in the *in vitro* collection) have been safely cryopreserved for the long term. A unique feature of our cryocollection is that for security reasons a representative backup selection of the frozen material is also preserved in cryotanks in Montpellier, France.

Thanks to the vast experience we gained with cryopreserving banana shoots,

droplet vitrification has become a robust protocol that has now been applied to conserve the biodiversity of more than 40 plant species. In addition, over the past 20 years we have trained 110 researchers from 47 countries on plant cryopreservation techniques at the ITC in Leuven.

Bart Panis

2013–today: Senior Scientist, Banana Conservation

2008–2013: Research Manager, Cryopreservation Research, KU Leuven

1995–2008: Postdoc Researcher, Banana Biotechnology, KU Leuven

"The National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India and I have greatly benefited with our association with the KUL/ITC Bioversity International lab at Leuven Belgium, over the last 18 years. In 2001, I undertook a postdoc fellowship (BOYSCAST, Govt. of India) in KUL for learning methods on in vitro conservation and cryopreservation of Musa genetic resources. Over the years this has helped in establishment of a strong program on Musa conservation in India. The association between NBPGR and Bioversity was further strengthened during 2009–12 under a collaborative project funded by the GCD, when a set of Musa germplasm was cryobanked in Delhi, and shipped to the ITC for safety duplication. Dr Bart Panis has been visiting NBPGR as a Resource Person to impart training under the Centre of Excellence programme between ICAR–Bioversity International since 2004, till date. In all, the ITC–KUL–NBPGR partnership has been extremely (banana) 'fruitful'!"

Dr Anuradha Agrawal
Principal Scientist & Officer-in-Charge
Tissue Culture & Cryopreservation Unit
ICAR-National Bureau of Plant Genetic Resources

The state of the world's plant genetic resources

Can you imagine trying to estimate all the plant genetic resources conserved and used in every country in the world? And assess the extent of use, conservation actions and investments? And analyze the main gaps and needs in plant genetic resource conservation and use? This mammoth task is undertaken periodically by the Commission on Genetic Resources for Food and Agriculture (CGRFA) at the Food and Agriculture Organization of the UN (FAO).

The resulting document is called the *State of the World Report on Plant Genetic Resources for Food and Agriculture* (SoWPGR). It is accompanied by a *Global Plan of Action for Plant Genetic Resources for Food and Agriculture* which guides countries to assess, conserve and use plant genetic resources.

Bioversity International, because of our mission and expertise to conserve and use plant genetic resources for food and agriculture (PGRFA), made important contributions to the two SoWPGR reports, which came out in 1996 and 2010.

The first SoWPGR report represented the state of knowledge of the conservation and use of PGRFA across the world in 1995 and provided the foundation for the *Global Plan of Action* and a baseline to monitor progress. Bioversity (as IBPGR – the International Board for Plant Genetic Resources and then as IPGRI – the International Plant Genetic Resources Institute) played an important role in its preparation during the early 1990s. We were in a strategic position to assist FAO due to our expertise in all the key areas of PGRFA, our coordination of the regional PGRFA networks, our network of regional offices, and our regular contact with almost all the countries. We supported individual countries to prepare their reports through a well-targeted participatory process and a standardized procedure to collate information, resulting in 154 countries producing reports. We also organized sub-regional and regional meetings and prepared the regional synthesis reports.

SoWPGR-2 describes the most significant changes since the first SoWPGR report and outlines major continuing gaps and needs. The preparation of SoWPGR-2 was done slightly differently from the first report. The CGRFA still requested countries to prepare their national reports following set guidelines, but instead of regional reports, there were in-depth thematic studies on specific topics: climate change, nutrition and health, and indicators for genetic erosion and seed systems. This new approach was useful to better understand aspects that cut across individual countries and regions.

Bioversity worked together with FAO in a joint technical committee to guide the preparation of the reports. We assumed specific responsibilities in the information-gathering process, organized regional meetings and authored or co-authored several chapters of the SoWPGR-2. We

also provided substantial organizational, technical and analytical inputs.

Both Bioversity and our partners benefited from the process directly or indirectly in terms of capacity building, strengthening relations with scientists worldwide, and increasing our knowledge of the actual situation with respect to gaps and needs as a basis for priority setting, project development and institutional strengthening. The SoWPGR also supplied a framework that directly contributed to policy development at all levels. Bioversity's role as the coordinating body of the CGIAR System-wide Genetic Resources Programme, provided us an important opportunity through the SoWPGR preparation process to contribute to advanced conservation, plant breeding and information management technologies and to the establishment of a general legal framework in which the global programmes could flourish.

Ehsan Dulloo

2016–today: Senior Scientist and Team Leader, Integrated Conservation Strategies

2015–2016: Senior Scientist and Component Leader, Conservation

2012–2015: Programme Leader, Conservation and Availability

2011–2012: Senior Policy Officer, Plant Genetic Resources, Food and Agriculture Organization of the UN (FAO)

2004–2011: Senior Scientist, Conservation of Agricultural Biodiversity

2002–2004: Scientist, Conservation, Management of Germplasm Collection

1999–2002: Scientist, Germplasm Conservation

Jan Engels

2012–today: Honorary Research Fellow

2010–2015: Coordinator, CacaoNet

2008–2016 Coordinator, European Genebank Integrated System (AEGIS)

2005–2011: Genetic Resource Management Advisor, including acting Director of the International Network for the Improvement of Banana and Plantain (INIBAP)

1995–2005: Director, Genetic Resources Science and Technology Group

1992–1995: Group Director, Germplasm Maintenance and Use

1988–1991: Coordinator for South and Southeast Asia, New Delhi

The state of the world's forest genetic resources

The first ever *State of the World's Forest Genetic Resources* (SOW-FGR) Report was published by the Food and Agriculture Organization of the UN (FAO) in 2014. Bioversity International's Forest Genetic Resources team took responsibility for reviewing the state of knowledge in the relevant research arenas and writing them up in a series of background pieces. The report catalyzed our efforts to develop a global programme for forest genetic resources conservation and use.

More than a decade ago, Bioversity and FAO established a set of regional networks for forest genetic resources, convening forest scientists from many of the forested nations in Asia, Africa, Europe and Latin America. Bioversity coordinated these networks from their inception. The generation of the SOW-FGR Report was an opportunity for the networks and other partners around the globe to review research results and tell us what gaps and priorities for research and action they had in each region. It drew from these scientific reviews to complement information gleaned from the country reports which were submitted by most forested nations.

The SOW-FGR, in turn, informed the development of FAO's *Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources*. Our team worked towards a global programme for forest genetic resources that would be fully compatible with the 27 Strategic Priorities for Action documented in the Global Plan of Action, and it is what guides our research, education and information-sharing projects still today.

One example is the research we carried out to benefit rural people in Central Asia and future generations around the globe. 'Conservation for diversified and sustainable use of fruit tree genetic resources in Central Asia' contributed to the conservation and sustainable management of wild and semi-domesticated populations of three globally significant fruit tree species: apple, apricot and walnut. We worked with our research partners to describe patterns of genetic diversity and the nutritional composition of the fruits and to identify valuable populations for conservation using biochemical and molecular approaches combined with spatial threat analyses. We strengthened capacity by training local practitioners and PhD students and by working closely with national partners from the three participating countries in every step of the project.

Judy Loo

2017–today: Honorary Research Fellow

2009–2016: Forest Genetic Resources Leader

"One of the first collaborations between Bioversity International (as IPGRI – the International Plant Genetic Resources Institute)'s Forest Genetic Resources Programme and FAO was the organization of a regional workshop on in situ conservation of genetic resources of woody species in arid and semi-arid areas. It was held in February 1994 in Ouagadougou, Burkina Faso, and attended by scientists, forest managers and agriculturalists. In his closing speech, the Minister of Environment, said that he wondered what in situ conservation of genetic resources meant when asked to support the workshop, but, he added, after listening to the report of the meeting he now understood that in situ conservation of genetic resources is what we do every day. There could not have been a better conclusion for the workshop. It is an example of how the contribution of research and the effective interaction of the research community can improve the awareness and understanding of the importance of daily management activities, and policies, to conserve genetic resources for the future. More recently, research played a key role in the preparation of the first SOW-FGR report, through active participation and support of regional networks, APFORGEN, EUFORGEN, LAFORGEN and SAFORGEN, in all the different stages of the process. Forest genetic resource networks are an important support for the implementation of the Global Plan of Action for Forest Genetic Resources."

Oudara Souvannavong, Retired Biodiversity Team Leader, Forestry Department, FAO

A 10-year road map for Mesoamerica

Mesoamerica, one of the main centres of domestication and diversification of globally important crops, hosts a wealth of plant genetic resources for food and agriculture which can be used to adapt to climate change.

Hurricanes and extreme weather events are already common in the region and are getting more frequent and more intense. Decreases or failures in crop production will seriously affect the food security and livelihoods of resource-poor farmers and vulnerable groups. This is why in 2010 a delegation approached me, representing the Central American focal points to the International Treaty on Plant Genetic Resources for Food and Agriculture (The Plant Treaty) – Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama – to ask if Bioversity International would lead a proposal on their behalf in response to a call from the Benefit-sharing Fund of the Plant Treaty. This is how the idea for the 'Strategic Action Plan to Strengthen the Conservation and Use of Mesoamerican Plant Genetic Resources in Adapting Agriculture to Climate Change' (SAPM) emerged.

To formulate the SAPM, we first conducted a diagnosis of the current state of affairs of PGRFA and climate change, and then worked collaboratively to identify strategic priority actions. We considered ten Mesoamerican crops and their wild relatives: maize, bean, cassava, sweet potato, cucurbit, amaranth, pepper, papaya, avocado and a native forage – prioritized for their importance for food security; their potential to adapt to climate stresses; and their contribution to diet diversity and income generation.

In the analysis, we included 384 cultivated species and their wild relatives and investigated: future climate impact to 2050; diversity gaps in plant genetic resources conserved in genebanks; germplasm conserved in genebanks with characteristics for potential adaptation to future climates; status of *in situ* conservation of wild relatives; and priority areas that would best conserve diversity of the majority of plant genetic resources of these species in the region. We combined data from datasets and scientific papers with interviews with 144 representatives of local and indigenous farmer groups in five countries in order to get a full understanding of the state of conservation and use of plant genetic resources by smallholder farmers.

In an unprecedented consultation process, we iterated between the diagnosis and various suggested activities in a series of regional meetings, convening more than 100 representatives of different sectors of national governments (agriculture, environment and health), regional government organizations, universities, regional and international agriculture organizations, farmers, civil society and donors.

The SAPM comprises activities under six thematic components: (1) on-

farm, *in situ* and *ex situ* conservation; (2) sustainable use under changing climates; (3) institutions and policies; (4) education and building capacity; (5) regional coordination frameworks and mechanisms; (6) resource mobilization.

On 1 August 2013, the Central American Agricultural Council agreed to support the SAPM at its Ordinary Meeting of Ministers held in Panama City. Thereafter, countries have used it to justify the inclusion of genetic resources in policy instruments (Costa Rica), advance the establishment of a National Genetic Resources Council (Honduras), and secure funding to implement participatory plant breeding focused on native crops (Guatemala).

Marleni Ramirez

2015–today: Regional Representative for Central and South America

2005–2014: Regional Director for the Americas

"The SAPM … has contributed to the visibility and inclusion of this issue [of genetic resources] in different policy instruments of high relevance for the agricultural sector in Costa Rica: National Seed Policy, Agricultural Sector Policy and National Development Plan. Finally, in the proposed reform to the Seed Law, the theme of support for the conservation and use of plant genetic resources has been presented as one of the important functions assigned to the National Seed Office. The SAPM was proposed for a period from 2014 to 2024 but we believe that it will continue to be a guiding instrument for actions with a projection and validity for many years to come."

Ing. Walter Quirós Ortega

Executive Director, National Seed Office, Costa Rica

Securing chocolate's future

The world's chocolate is under threat. Climate change and pests and diseases are affecting production, wiping out well over a third of all cacao produced. Like other crops, breeders could use the wealth of diversity of *Theobroma* species (the scientific name for the family that cacao belongs to) to breed resistant quality varieties.

Traits for resistance might exist in international and national collections of cacao. Many of these materials are unique and cannot be collected again, as they no longer grow in the forests or traditional farming systems where they once grew, owing to deforestation, changing agricultural practices and more recently changing climates. Even when the diversity is collected, very little is used leaving the vast majority totally untapped!

Millions of smallholder farmers across tropical regions of the Americas, Caribbean, Africa, Asia and the Pacific depend upon cocoa for their livelihoods. In a context of changing climates and evolving pests and diseases, it is imperative that they have access to quality, well-adapted planting materials, and that they receive a fair price for their work.

Since 1993, Bioversity International has worked, in close partnerships with the private and public sectors, to save cacao and promote its diversity. We coordinated the development of the global strategy for the conservation and use of cacao genetic resources as the foundation of a sustainable cocoa economy (from farmers through to research and consumers), through CacaoNet, a worldwide cocoa network of public and private sector stakeholders.

Our approach is to leverage the world's love of chocolate to increase appreciation of the diversity of its base ingredient, cacao. This is to generate public awareness and resources to save collections and to empower the millions of farmers growing cocoa to get a fair price. The Cocoa of Excellence Programme, and the International Cocoa Awards which we have organized every two years since 2009 with our partner the Salon du Chocolat, bring together 50 cocoa-producing countries to recognize and reward cocoa quality and diversity of flavours. In 2018, we piloted the very first cocoa bean auction in partnership with Chocoa, an annual initiative to support fair and sustainable cocoa value chains. The beans we auctioned ended up tripling their starting price.

One challenge we have faced in the Cocoa of Excellence Programme is that, unlike coffee, wine and other highly differentiated food products, cocoa does not yet have international standards to assess its quality and flavour. We are now leading the development of the first international standards so that all cocoa value chain actors can speak a common language.

According to a survey of cocoa actors in producing countries, which we conducted after ten years of activity, the Cocoa of Excellence Programme contributes to creating profitable relationships with bean buyers and providing an international platform for producers. It helps improve

Credit: Salon du Chocolat

bean quality and so increases their market value. The Cocoa of Excellence Programme recognizes the importance of good fermentation and drying and is effective in promoting cocoa quality, flavour sensory evaluation and the concept of 'terroir'. Participating cocoa-producing countries said that with each edition they participate in, their capacity to seek and recognize excellence in cocoa quality and flavour has improved.

Brigitte Laliberté

2010–today: Scientist, Cacao Genetic Resources and Diversity, Coordinator of the Global Network for Cacao Genetic Resources – CacaoNet, Coordinator of the Cocoa of Excellence Programme

2008–2010: Coordinator of the World Bank funded project 'Collective Action for the rehabilitation of the global public goods in the CGIAR genetic resources system: Phase 2'

2003–2008: Scientist, Crop Genetic Diversity Conservation Strategies, Crop Trust

1999–2003: Research Assistant, European Cooperative Programme on Genetic Resources

1996–1998: Scientific Assistant, Impact Assessment and Project Evaluation

"Cocoa of Excellence, formed by a small group of passionate cocoa and chocolate people in 2008, is one of only two programmes in the cocoa sector and in the world which focus on what the farmer gives us—the cocoa beans. Bioversity quickly joined us in the programme, bringing with them the same commitment to the cocoa farmer, their livelihood and their recognition, that is the basis for Cocoa of Excellence. But they bring far more than just passion – their staff is dedicated and committed to excellence in organization and execution of programmes such as ours. Bioversity, and in particular Brigitte Laliberté, now stands as the leader and champion of the programme."

Edward Seguine (Centre)
Seguine Cacao, Cocoa & Chocolate Advisors and Guittard Chocolate

Coconuts

More than 100 million people living in fragile coastal areas of the tropics depend on coconut for their livelihoods. Coconut provides many essentials: food and water; timber and leaves to build homes; and oil and copra for fuel and as a source of income. Environmental disasters, such as cyclones and tsunamis, frequently leave coconut as the last tree standing, able to protect and sustain communities in the immediate aftermath of the disaster, providing food, water and shelter while people rebuild their lives. Despite its importance, however, coconut was something of an orphan crop, ignored by mainstream research and development for agriculture

Dr Gabrielle Persley, co-founder of the International Coconut Genetic Resources Network.

With the leadership and support of CGIAR, in 1992, Bioversity International (as IBPGR – International Board for Plant Genetic Resources) took up the challenge of promoting the global conservation and use of coconut genetic resources through a network, the International Coconut Genetic Resources Network, COGENT. Membership grew from 15 to 39 producing countries, and now represents 98% of global production. In collaboration with the International Treaty for Plant Genetic Resources for Food and Agriculture, Bioversity also helped to establish five international coconut genebanks, along with strong links to 19 national collections. Together, the genebanks conserve more than 1,000 distinct accessions. During 2019, COGENT will support these collections via selected genebank appraisals for planning medium-term capacity and infrastructure development.

In August 2018, Bioversity published COGENT's new *Global Strategy for Coconut Genetic Resources 2018–2028*. The Strategy is the product of consultation with more than 90 expert stakeholders in the conservation and use of coconut genetic resources, who made more than 400 contributions over seven years. It was driven and compiled by Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)-seconded coordination. With the support of Bioversity and partners, COGENT has continued to coordinate the refinement of this progressive global strategy. The Australian Centre for International Agricultural Research

and the Australian Department of Foreign Affairs and Trade are now considering further support to kick-start implementing the Strategy.

After more than 25 years, in 2019, for strategic reasons, the COGENT Secretariat is being transferred from Bioversity to the Jakarta-based International Coconut Community (ICC). COGENT's transfer heralds a new era for coconut conservation and use, at a time when global demand for coconut products is growing exponentially. The estimated global market for coconut water alone is predicted to be in the order of US$10 billion by 2030. The new host, ICC, is strategically positioned to support coconut conservation through use.

Vincent Johnson

2018–today: ad interim COGENT Coordinator

2008–today: Science Writer, Editor and Process Manager

"In collaboration with CIRAD's southern partners, the work with Bioversity and COGENT helped fulfil part of CIRAD's mission to produce and transmit new knowledge to support innovation and agricultural development. It also provided opportunities to lead or participate in various coconut projects across the tropics, that helped informed and improved the impact of CIRAD's coconut research from genomics, through ethnology and multifunctional landscape management, to coconut processing and value-chain dynamics."

Drs Roland Bourdeix (Coconut Diversity Specialist) and Alexia Prades (Food Processing and Post-Harvest Specialist). CIRAD

From left: Former COGENT coordinators Dr Alexia Prades, CIRAD; Dr Roland Bourdeix, CIRAD; Dr Lalith Perera, Coconut Research Institute, Sri Lanka, and former COGENT Chair; Vincent Johnson, Bioversity International and current interim COGENT coordinator

Incentives to conserve agrobiodiversity

Today, many low-income countries face a major challenge: how to safeguard the biodiversity maintained by smallholder farmers in their fields – which constitutes a national and global public good –while meeting those same people's development needs and rights?

For some crop varieties, with a particular culinary or cultural appeal for example, it is possible to develop marketing strategies. This means that the farmer benefits from increased income and is motivated to maintain them. But not all genetic diversity has market potential. For those without, a different type of incentive mechanism is required, which can reward farmers for providing a conservation service to society and compensate them for their efforts.

A novel solution to this dilemma takes Payments for Ecosystem Services (PES) concepts and applies them to agrobiodiversity. 'Payments for Agrobiodiversity Conservation Services' (PACS), an innovative approach developed by Bioversity International, provides farmers with incentives which they choose themselves (often farm inputs, machinery or school materials). PACS brings together many different kinds of partners in a platform where they collectively can learn more about conserving and using their shared agrobiodiversity: prioritizing, setting conservation targets, designing cost-effective interventions and implementing farmers' rights, for example.

PACS has been successful in Bolivia (quinoa), Ecuador (maize), Guatemala (maize and beans), India and Nepal (minor millets), Peru (quinoa, amaranth, potato), and Zambia (crop wild relatives). Revisiting five communities in the Region of Puno, Peru, after five years, we found that, even without further rewards, 30%-50% of farmers were still cultivating the four threatened quinoa varieties the PACS project had reintroduced. PACS' success is largely due to its building on farmers' existing preferences for traditional varieties. Since it supports what they already want to do, PACS is cheaper than conventional PES interventions and generates high rates of persistence after the incentives end. After one year of PACS participation, many farmers express willingness to participate again even without further incentives, as long as the project facilitates their access to seed of the threatened varieties in question.

The Ministry of Environment of Peru and a number of Regional Governments have voiced interest in replicating PACS incentive mechanisms elsewhere as a means of meeting regulatory commitments under the Convention on Biological Diversity, the International Treaty on Plant Genetic Resources for Food and Agriculture and national legislation.

Plans are in place to use PACS approaches to conserve the genetic diversity of a further 15–20 crops important for climate change adaptation and food security.

Future challenges include:

- Accessing sufficient seed of threatened varieties. Community seedbanks and local cooperatives can help. For example, the recently designated Quinoa Biodiversity Park in Caminca, Puno, includes five quinoa varieties that were subject to PACS intervention in 2015–16.
- Securing increased conservation programme funding and generating sustainable demand for threatened varieties. In this context, we will continue to explore further private-sector direct support, continued niche product market development and the potential role of public food procurement programmes.

Adam G. Drucker

2015–today: Principal Economist

2012–2015: Research Theme Leader, *In situ*/On-farm Conservation

2008–2011: Senior Scientist

"Now that we have realized the virtues of these varieties, we will strive to keep them alive, even if the project does not go on."

Santusa de López, Farmer in the Community of Aguaquiza, Nor Lipez Province in Potosi, Bolivia

Developing the science of on-farm conservation

In the early 1990s, it became clear that *ex situ* facilities could not accommodate the full range of useful diversity and do not conserve dynamic processes of crop evolution and farmer management. Although the newly formed Convention on Biological Diversity was committed to *in situ* conservation, the science and practice of how to actually implement it was missing. And so began a quest to see if farmers were still maintaining diversity on farm, and if so why. We wanted to know how research could support them to meet their different production and cultural needs under changing environmental and sociocultural conditions.

Bioversity International collaborated with over 60 institutions worldwide to develop a research programme across nine countries, bringing together experts in ecology, botany, genetics, agronomy, plant breeding, anthropology, economics and policy. Over 20 years, the project team worked with partners from low-income and more advanced economies with the common goal of providing tools and methods for understanding and tapping the potential of crop genetic diversity on farm.

The global team revealed that sustainable production and rural livelihood strategies are firmly linked with conservation of the crop genetic diversity growing in farmers' fields. We developed novel ways of gathering and using data about traditional varieties and traditional farming systems through participatory diagnostic and empirical approaches. These included methods to identify ways to support the farmers who grow these varieties, and quantified the benefits of this diversity to farming communities.

Tools developed to assess the genetic diversity on farm included: its measurement and management from a farmer's perspective; how farmers make genetic diversity choices to manage stresses such as drought or diseases; and how crops evolve in stressed environments under farmer management. One critical factor was characterizing farmers and famer communities who maintain crop genetic diversity and conducting assessments of the economic, policy, legal and institutional frameworks supporting or hindering them.

After 20 years of research, we had a scientific understanding of the multiple factors that influence whether farmers maintain or not genetic diversity on their farms. We understood the principles and applications of crop genetic diversity in agricultural ecosystems and in farmers' livelihoods, how to research these and how to provide institutional and strategic support.

The research set the agenda for the new work programme on agricultural biodiversity of the Convention on Biological Diversity in 2000 (Decision V/5). At a country level, project activities led to *in situ* conservation and on-farm management of crop genetic diversity being integrated into the national and/or provincial plans in Burkina Faso, Ethiopia, Hungary, Mexico, Morocco, Nepal, Peru and Vietnam. But perhaps the greatest legacy was that it laid the foundations for much of Bioversity's future research agenda supporting farmers who use traditional crop varieties in sustainable agricultural production and agroecological resilience. Research areas that grew from this original project covered: tropical fruit trees; diversity for pest and disease management; genetic resources policy; fruit trees in Central Asia; date palm in North Africa; and bananas in the Great Lake states.

Devra Jarvis

2012–Present: Principal Scientist, Genetic Diversity Productivity and Resilience

2000–2011: Senior Scientist, Agricultural Biodiversity and Ecosystems

1996–1999: Scientist, *In Situ* Conservation

"The wisdom and hard work of millions of farmers since the advent of agriculture are finally acknowledged and explained in this landmark book … the authors need to be congratulated for a detailed account of the value of and the need for conserving traditional varieties, which is the key element for transforming the present dead-end agriculture into a sustainable model based on diverse genetic crop makeup, complemented by diverse cropping systems."

Hans R. Herren, Co-Chair, The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), commenting on the book summarizing 20 years of on-farm conservation research, *Crop Genetic Diversity in the Field and on the Farm*

Date palms in North Africa

In the desert oases of the Mahgreb, across North Africa, a focus on fewer than ten commercially valuable varieties of date palm put pressure on the vast diversity of hundreds of date varieties and entire oasis ecosystems. A Bioversity International project worked closely with oasis farmers, researchers, extension staff and policymakers in Algeria, Morocco and Tunisia to broaden the genetic diversity of the date palm varieties they grew.

Starting in 2001, the 'Maghreb Date Palm Project' attacked the problem on several fronts. Promising varieties threatened with genetic erosion were screened so that they could be multiplied and distributed to farmers. Dates do not breed true from seeds, and farmers usually multiply date plants by replanting offshoots of the mother plant.

However, since the threatened varieties were rare, there were few offshoots to distribute, so we had to develop tissue culture techniques to produce more plants more rapidly. At the same time, the project helped to promote additional markets and different uses (for example using the leaves to weave baskets) for specific date palm varieties, to give farmers an incentive to grow them. The project helped researchers, extension staff from government and non-governmental organizations (NGOs), and farmers in the three countries to share knowledge and good practices about the management of date palm genetic resources.

Visiting the various oases, project partners identified almost 900 varieties of date palm, about 240 of which had not previously been recorded. Before the project started, only 10 varieties were available to farmers; now, the tissue culture laboratories are multiplying more than 70. In addition, many of the 'new' varieties are now safely conserved *ex situ* and *in situ*.

The project intended not merely to conserve varieties but to allow them to continue to develop in concert with changes in the ecology of oases and the communities that depend on them. This has been reflected in a general expansion of the diversity of other crops in the oases, all of which depend on the presence of

thriving date palms. As a result, in 2011, two sites – the Ghot system in Algeria and the Gafsa oasis in Tunisia – were formally recognized as Globally Important Agricultural Heritage Systems by the Food and Agriculture Organization of the UN (FAO).

A key impact came from work with policymakers to change the laws and incentives to promote conservation of date palm genetic resources, which before the project were promoting genetic uniformity. In Algeria, new plantations now receive a government subsidy only if rarer varieties make up at least 20% of the date palms. Tunisia too has adopted the results of the project (Law 2008-73) and has ordered thousands of plants of rarer varieties, to satisfy demand for diversity from farmers.

Before this project, the genetic diversity of date palms and the other plants of the oases was being lost. Now, several projects have continued to duplicate the results of the Maghreb Date Palm Project. By working with farmers, NGOs and governments, their biodiversity is being conserved and used to improve livelihoods and the oasis ecosystems.

Noureddine Nasr

2004–2007: Coordinator, Bioversity International Regional Office in North Africa

2002–2007: Regional Coordinator, GEF/UNDP date palm project

Plant Production and Protection Technical Officer, FAO – sub-regional office for North Africa

Mapping threats to tree species

Understanding the impact of anthropogenic threats on tree species' survival and fitness is important for the planning of future conservation and restoration efforts.

Since the late 1990s, Bioversity International colleagues Prem Mathur and Luigi Guarino, with colleagues from the International Potato Center and the University of Birmingham, had been using geographic information systems to locate likely distribution of wild crop species by combining knowledge of the plant's growing habitat with ecological maps. These distribution maps could be overlaid with climate maps, which allowed us to prioritize the most threatened areas for conservation, which is what we did to define conservation priorities in a 2006–2010 project on *Prunus africana*, the important African cherry tree.

Climate change is not the only threat however. Overexploitation, habitat conversion, overgrazing and fire also pose a threat to many species. Multiple threats can combine to put the survival and fitness of important species at risk.

I had the opportunity to develop a species-specific threat mapping methodology in two projects focusing on important fruit tree species in West Africa and Central Asia. Using the framework, we can predict, at a fine scale, where multiple threats are likely to have a negative impact on suitable habitat, species by species, in the present and near future. Our partners and local experts from national organizations, such as the Environmental Institute for Agricultural Research (INERA) in Burkina Faso and the National Agrarian University in Kyrgyzstan, provided key information and knowledge.

The visual and spatially explicit representation of the threats and their predicted impact, in the form of maps with different threat levels, make the results easily accessible and understandable to decision-makers from private and public agencies.

The results of these studies are now being used to efficiently plan species-specific restoration and conservation actions at a high spatial resolution. A project with the Asia Pacific Forest Genetic Resources Programme (APFORGEN) is helping countries to establish areas for conservation of forest genetic resources,

by combining information about threats with information about the geographic distribution of genetic diversity. As well as having recreational and ecosystem service functions, these *in situ* areas will be used to guarantee the availability of adapted seed sources for forest and landscape restoration.

Hannes Gaisberger

2011–today: GIS Specialist: spatial analysis of genetic and climatic data to define conservation priorities and threats

2009-2011 Programme Specialist, Bioversity International Collecting Missions Database

"The project brought a great outcome for better management of main food tree species in Burkina Faso. It sums up knowledge of different research and allows us to have an overview of these species in order to take good decisions for sustainable management."

ZERBO Guibien Cleophas, Researcher at Centre National de Semences Forestières (Burkina Faso)

Crop wild relatives

Crop wild relatives are wild plant species closely related to crops. People have been using them through domestication ever since agriculture started. The wild relatives of crops are a vital pool of genetic variation that can be used in breeding new varieties of crops better adapted to stress, disease, drought and other factors, thus safeguarding future agricultural production under climate change.

All the major conventions and treaties (Convention on Biological Diversity in 1993, Food and Agriculture Organization of the UN (FAO)'s 'Global Plans of Action' in 1996 and 2010, the International Treaty on Plant Genetic Resources for Food and Agriculture in 2001 and more recently the 2030 Agenda for Sustainable Development) recognize that conserving crop wild relatives needs to be a national and global priority, and have set targets to monitor their conservation status.

Crop wild relatives were part of the collecting objectives of Bioversity International (as IBPGR – the International Board for Plant Genetic Resources) from its creation, as we recognized their importance for the future of agriculture. Early research focused on working out which species are relatives of priority crops, where they grow, what threats they face and the best techniques to collect and store their seeds. We came to appreciate conservation of wild relatives *in situ* to preserve their evolutionary potential through interactions between the plants and their environment.

A 5-year project, with national partners from Armenia, Bolivia, Madagascar, Sri Lanka and Uzbekistan, established a solid basis for the long-term conservation of crop wild relatives and produced a range of tools, manuals and products that guide the conservation and use of these resources globally. One important result was the *Core Descriptors for In Situ Conservation of Crop Wild Relatives v.1*, which facilitated the compilation and exchange of *in situ* conservation data and helped build national and international information management systems.

The current phase of research concentrates not so much on rescuing threatened seed of important crop wild relatives and conserving it in genebanks, but on multiplying the capacity of countries worldwide, low-income and advanced, to prioritize crops for national and global food security and livelihoods, conduct threat analyses and articulate *in situ* conservation strategies.

One milestone has been in the South African Development Cooperation (SADC) region to enhance national scientific capacities to conserve crop wild relatives and identify traits for potential adaptation to climate change. Together we developed National Strategic Action Plans in Mauritius, South Africa and Zambia to conserve and use these species. We jointly documented and assessed the diversity of crop wild relatives, identified priority species, and delineated strategic actions

for their conservation and use. In Zambia we worked with farmers to develop incentive mechanisms to conserve these wild relatives, including calculating the costs of conserving them.

Regionally, over 50 scientific staff from 14 SADC countries were trained on *in situ* conservation methodologies, predictive characterization and pre-breeding to better conserve and use these resources. We have developed a toolkit for planning conservation and use of crop wild relatives. With our SADC partners we have developed a concept for a regional *in situ* crop wild relative conservation strategy.

Bioversity with the University of Birmingham and FAO is now pioneering a global network for *in situ* conservation, to complement conservation in genebanks, establishing links with breeders to provide access to these globally important resources for sustaining our agriculture and food systems.

Ehsan Dulloo

2016–today: Senior Scientist and Team Leader, Integrated Conservation Strategies
2015–2016: Senior Scientist and Component Leader, Conservation
2012–2015: Programme Leader, Conservation and Availability
2011–2012: Senior Policy Officer, Plant Genetic Resources, FAO
2004–2011: Senior Scientist, Conservation of Agricultural Biodiversity
2002–2004: Scientist, Conservation, Management of Germplasm Collection
1999–2002: Scientist, Germplasm Conservation

"As Chairperson of the project Steering Committee, I observed firsthand the impressive outputs of the multi-stakeholder endeavour. The project engendered a unique Community of Practice (COP) which developed and validated innovative tools. These tools enabled the mapping of crop wild relative locations in resource-challenged countries that are home to this irreplaceable germplasm that are veritable repositories of novel traits for crop improvement. The trained scientists can now harness these traits for breeding resilient crop varieties to enhance crop production systems, as well as improving the nutritional qualities of staple crops. The COP also serves as a model to create a global network that could facilitate the conservation and sustainable use of crop wild relatives."

Chike Mba, Plant Production and Protection Division, FAO, Italy

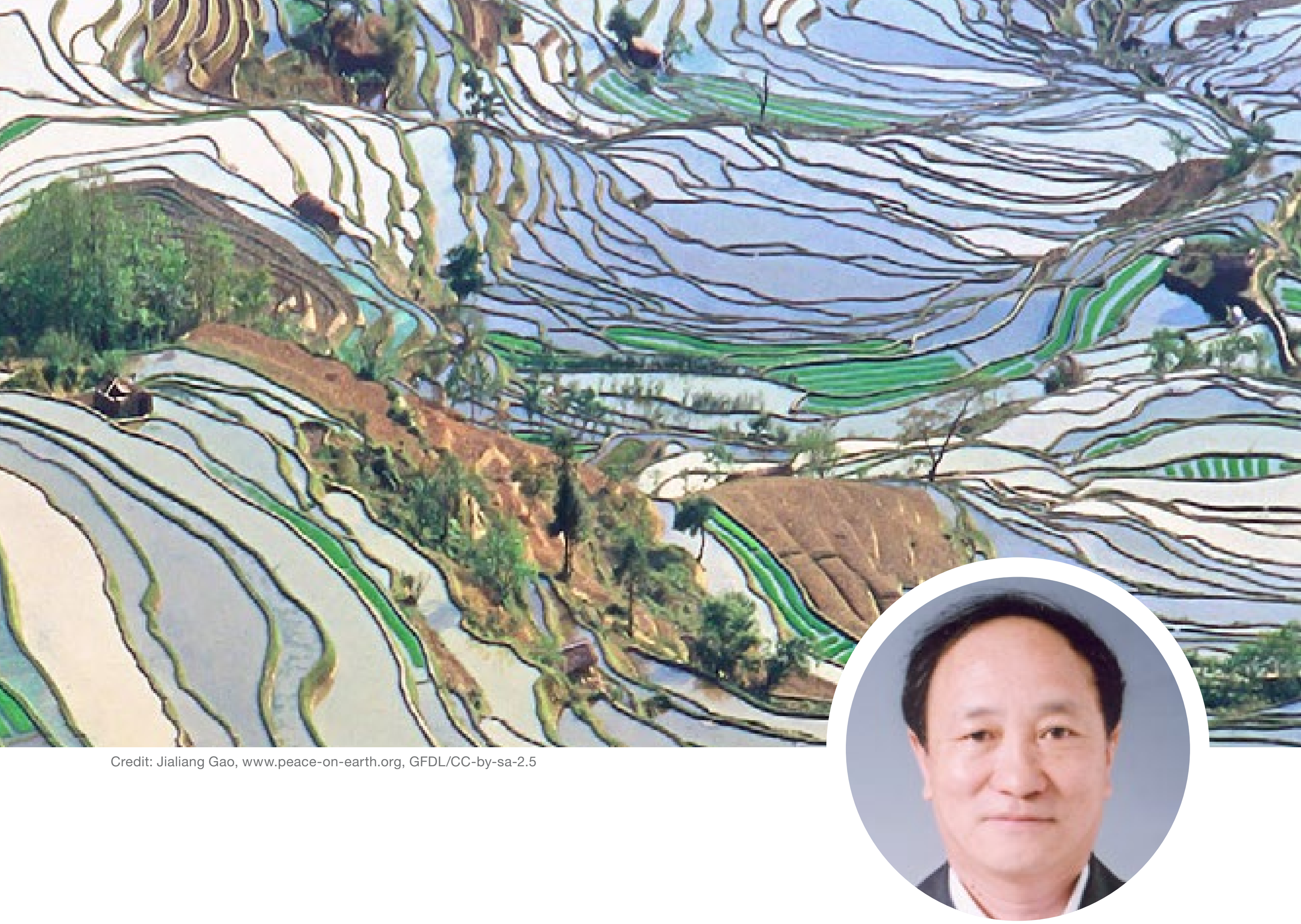
30 years in China

China, with one of the largest agricultural sectors in the world, particularly in terms of the number of households that depend on farming, has been an important country for Bioversity International for 30 years. In addition to specific projects in China, we also maintain close collaborations with Chinese academies and scientists. The overall goal of this effort is to ensure that agricultural biodiversity is conserved and used to improve the resilience of farming systems in China and support the livelihoods of the farmers who manage them.

One approach over the years was to collaborate with Chinese researchers to strengthen their abilities for safe conservation. Some work focused on storage, such as protocols for ultra-dry seed storage and for cryopreservation and *in vitro* storage. As a result, China now hosts one of largest crop collections in the world. Another was to make large collections more useful to breeders by characterizing and evaluating seeds and developing tools for data management, including adoption of Bioversity descriptors and identifying useful traits and materials with phenotypic and molecular tools. A third focused on the conservation and use of plant genetic resources by farmers on their farms. Given the number of farmers in China, it was important to reach out to them. Working with partners, we offered training on the on-farm management of agricultural biodiversity and promoted *in situ* conservation of wild rice.

Important projects also increased the economic value of biodiversity to farmers. For example, one project showed that the benefits of growing farmers' rice varieties in the Hani terraces were greater than modern cultivars, because older varieties with more nutrients fetch a premium in the market. Mixed fields demonstrate more resistance to pest and disease and require fewer inputs that can improve farmers' incomes. Overall yields of landraces and variety mixtures are also more stable from year to year.

Another project worked to increase diversity on farms. Working closely with Chinese partners, we evaluated thousands of accessions of buckwheat and oats to identify those that might be best adapted for future climates. These were assessed jointly by farmers and scientists, and the six most promising varieties for each of buckwheat and oat are now being scaled



Credit: Jialiang Gao, www.peace-on-earth.org, GFDL/CC-by-sa-2.5

up and promoted through demonstrations in ten households in each of three counties in Sichuan province.

As a result of our collaboration, the Chinese Academy of Agricultural Science established the first research group in the country on conservation and use of genetic resources of underutilized species. This has increased awareness of the importance of agricultural biodiversity for livelihoods in the country, which in turn should contribute to resilience and security.

Zongwen Zhang

2015–today: Regional Representative for Southeast Asia

2014: Senior Scientist, Genetic Resources of Underutilized Crops

2003–2014: Coordinator, East Asia

1989–2002: Assistant Coordinator, East Asia

"Bioversity's collaborative research with us has greatly contributed to the conservation and use of crop genetic resources in China."

Prof. Xinxiong Lu, Director of National Genebank, Crop Genetic Resources Centre of Institute of Crop Science of Chinese Academy of Agricultural Sciences

Community seedbanks

A community seedbank is an institution that local people govern and manage to maintain seeds for local use. Around the world, community seedbanks maintain thousands of locally adapted varieties of important food crops, facilitating their access by tens of thousands of farmers and allowing their further adaptation to changing conditions. They operate as local institutions of social organization, collective learning and community empowerment with key roles played by women. Community seedbanks have been around for about 30 years.

In 2011, I was part of the first national community seedbank workshop held in Nepal with seedbank pioneers Bhuwon Sthapit and Pitambar Shreshta. We looked back over the decades and asked: 1) What had been achieved and learned in these 30 years? 2) What roles could community seedbanks play in the light of challenges such as climate change, agricultural modernization and genetic erosion? A thorough systematic review followed this workshop, exploring the origins, evolution and prospects of community seedbank types around the world, their multiple functions and services, and their increasing importance in adapting to changing climates.

Applying what we learned, we engage not only in understanding community seedbanks, but also the practical work of establishing or developing them (including technical, organizational, policy and legal aspects) in Bangladesh, Bhutan, Bolivia, Burkina Faso, China, Ethiopia, Guatemala, India, Kenya, Madagascar, Mali, Nepal, South Africa, Sri Lanka and Uganda. Three elements stand out in these recent practical efforts: 1) bridging traditional knowledge with modern science to strengthen technical and organizational aspects, 2) adding value to the conservation function of community seedbanks through participatory crop improvement, seed production and marketing, and 3) linking community seedbanks to national genebanks to create synergies between *ex situ* and on-farm conservation and facilitate exchanges of knowledge and seed.

Today there are at least 500 operational community seedbanks around the world, a number that continues to expand as communities take into their own hands the management of their heritage seeds and knowledge. The next phase is to increase the power of individual community seedbanks by helping them to create networks for knowledge exchange, capacity building and collective action.

In Nepal, local organization Local Initiatives for Biodiversity, Research and Development (LI-BIRD) is joining the national agricultural system and Bioversity International to support the recently established national association of community seedbanks to facilitate joint learning, create more visibility and give a stronger political voice to community seedbanks.

In China, the Farmers' Seed Network is establishing new community seedbanks and assisting other organizations to do the same.

In India, government organizations and Bioversity have set up several community seedbanks as part of a climate change adaptation strategy.

In South Africa, the government and Bioversity are working on a national network of community seedbanks that connects them to the national genebank.

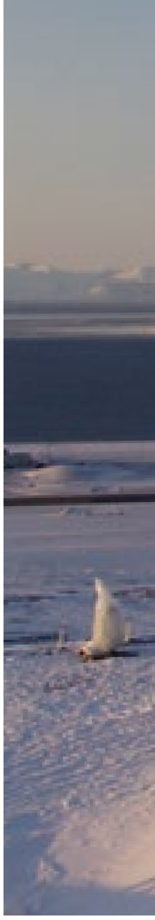
In 2018, together with partner organizations from Austria, Brazil, China, Nepal, the Netherlands, Peru and Zimbabwe, we created the Global Community Seedbanks Platform to provide technical, organizational and policy support to community seedbank efforts around the world. Much has been achieved on our journey, but more work remains to be done.

Ronnie Vernooy

2011–today: Genetic Resources Policy Specialist

"Thanks to the Gumbu seedbank, our seeds are now stored safely, we have learned new seed storing techniques and now store more seeds in our community. We exchange useful information about seeds and enjoy good times together."

The women of the Gumbu seedbank



Credit: Mari Tefre/Crop Trust

Establishing the Crop Trust

In the late 1990s, Bioversity International (as IPGRI – the International Plant Genetic Resources Institute) received an urgent request from an African national genebank for help to pay its electricity bill, because the government concerned was unable to provide the necessary funds. Without these few thousand dollars, the genebank risked losing its entire collection. This case was far from isolated and it was increasingly apparent that many genebanks, especially in low-income countries depended more on stability of funding than the absolute funds available. IPGRI saw the creation of an international endowment fund as an ideal solution to this situation. At the same time, it was proving increasingly difficult to secure the funding needed to maintain the CGIAR's own genebanks and in May 2000, the CGIAR Finance Committee endorsed IPGRI's recommendation to explore the establishment of an endowment fund to help provide stable and sustainable financing for the Centres' in-trust collections.

The two ideas came together, and throughout the spring and summer of 2000 we consulted with the Food and Agriculture Organization of the UN (FAO), various OECD countries, low-income countries, the Global Forum on Agricultural Research and a number of NGOs regarding the idea of establishing a fund dedicated to conserving plant genetic resources. Broad support was expressed for the idea.

In October 2000, IPGRI commissioned an independent consulting firm to assess the feasibility of establishing such an endowment and to determine a reasonable fundraising target. The consultants interviewed more than 130 individuals from governments, foundations and corporations in about 30 countries and concluded that up to US$260 million was a reasonable target, provided there was strong endorsement from key low-income countries, FAO, CGIAR and the World Bank.

In the following year, at IPGRI's request, the International Food Policy Research Institute and the University of California, Berkeley, undertook a study on the costs of operating genebanks. The study found that about $6 million was required per year to support the CGIAR genebanks. This, together with equivalent funding to support key collections in national genebanks in low-income countries, meant that approximately $13 million would be required annually, including administrative costs. In order to generate this amount, an endowment of about $260 million would be needed; the same figure that the consultants had considered feasible.

Credit: Mari Tefre/Crop Trust

Following further discussions, IPGRI (on behalf of CGIAR) and FAO agreed to jointly establish the Crop Trust. We formally presented the idea to the World Food Summit in Rome in June 2002, where it was well received. In July, 2002, at IPGRI's request, Imperial College, London published a report entitled *Crop Diversity at Risk: The Case for Sustaining Crop Collections*. The report argued that an endowment fund was needed to support genebanks around the world. In August 2002, IPGRI and FAO formally and publicly committed to establishing the Crop Trust at the World Summit on Sustainable Development in Johannesburg and launched its first website *Start with a Seed*.

Based on the recommendations of a meeting of potential donors in London in late 2002, IPGRI and FAO set up an expert panel, under the Chairmanship of Ambassador Fernando Gerbasi who had earlier chaired the negotiations for the International Treaty on Plant Genetic Resources for Food and Agriculture, to establish the Trust as a legal entity.

At its meeting in October 2003, the panel approved the Crop Trust's Constitution and other legal documents. Over the next few months, IPGRI and FAO secured the signatures of 12 countries on the Establishment Agreement (Cape Verde, Ecuador, Egypt, Ethiopia, Jordan, Mali, Morocco, Samoa, Sweden, Syria, Togo and Tonga).

On 21 October 2004, the Crop Trust was born. The following year, in 2005, the Crop Trust set up its inaugural Executive Board and Donor Council and began to operate as an independent legal entity. To this day Bioversity International maintains a close working relationship with its offspring, the Crop Trust.

Geoff Hawtin

1991–2003: Director General, International Plant Genetic Resources Institute

Reflections from Leadership: The beginning

Geoff Hawtin, Director General

International Plant Genetic Resources Institute

1991–2003

I joined the International Board for Plant Genetic Resources (IBPGR) as its second Director in 1991 following the departure of Trevor Williams. At that time IBPGR was a programme within the Food and Agriculture Organization of the UN (FAO), primarily concerned with surveying and collecting genetic diversity and, through convening expert working groups, devising and overseeing the development of *ex situ* conservation strategies for specific crops. From 1991 to 2003, we grew from being a FAO programme of 60 people and a budget of US$9 million to being an independent CGIAR research centre of 300 staff in 28 countries, four regional offices and a budget of $30 million.

In 1993, we developed a new strategic plan 'Diversity for Development'. This set the scene for our transition, leaving FAO in 1994 and becoming the International Plant Genetic Resources Institute (IPGRI). The new strategy shifted the focus from pure conservation to getting genetic resources into use, with new focuses on aspects such as ethnobotany, policy and neglected species.

Throughout the 1990s, IPGRI was the leading institution within CGIAR with respect to genetic resource policies. In 1994, CGIAR established the System-wide Genetic Resources Programme under IPGRI's leadership. At the same time, the semi-independent Genetic Resources Policy Committee was established to keep CGIAR members and centres abreast of policy developments, with Prof. M. S. Swaminathan as Chair. IPGRI provided the Secretariat for the committee. We also represented CGIAR at the negotiations leading to the adoption of the Convention on Biological Diversity and the subsequent meetings of the Conference of the Parties. In addition, we spearheaded CGIAR's involvement in the negotiations leading to the creation of the International Treaty on Plant Genetic Resources for Food and Agriculture. IPGRI was the centre primarily responsible for negotiating the agreements that in 1994 brought the CGIAR Centres' in-trust germplasm collections under the auspices of FAO.

In the late 1990s IPGRI led the development of the Crop Trust, which in 2004 was established as an independent, international institution concerned with financing *ex situ* collections around the world, primarily through its endowment fund.

In 1994, following a decision by CGIAR funders, the International Network for the Improvement of Banana and Plantain (INIBAP) became a programme of IPGRI.

Edmond De Langhe, Director

International Network for the Improvement of Banana and Plantain

1985–1991

The International Network for the Improvement of Banana and Plantain (INIBAP) was created in 1985 as an independent research body with the financial support of several CGIAR donor institutions. It was designed as a network of national programmes with a small secretariat. Since no comparable network in the realm of CGIAR could serve as a model, the construction of INIBAP was quite a challenge.

The first priority was to initiate a community of banana researchers, so they could at last discuss banana topics on regional and global scales. We realized this in two ways. The first was holding thematic workshops such as on taxonomy, pests and diseases. The second was appointing regional coordinators for four regions: Asia-Pacific – which contains the large primary centre of banana diversity; West Africa – dominated by plantain bananas; East Africa – with its unique highland cooking bananas; and tropical

America – where a range of introduced cooking and dessert banana cultivars had quickly become popular both locally and for export. This basic organization proved to be successful and has been maintained ever since.

Key programmes were launched to realize the network's objectives:

The International *Musa* Testing Program was established at several research stations and institutes in the tropical world to evaluate new hybrids from genetic improvement programmes and compare them with local popular cultivars.

The Bioversity International *Musa* Transit Center (ITC) was established at KU Leuven in Belgium to collect and preserve the entire diversity of the genus, wild species included, and deliver virus-free cultivars and wild taxa on request to a rapidly growing body of researchers.

The *Musa* Germplasm Information System to provide taxonomic and other information for the ITC accessions, so the recipient could select accessions with the traits they desired.

These programmes are still running on a steadily growing scale and prove that we were on the right track in the construction of INIBAP.

I was greatly encouraged by an enthusiastic Board of Trustees with Dr Hubert Zandstra as Chair, the vivid interest of donor group members, the abundant advice from the International Development Research Centre, and the generous material help from the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), the host institute in France.

Lauritz Holm-Nielsen, Board Chair

International Plant Genetic Resources Institute

1993–1994

In 1993 I took over as Chair of the International Plant Genetic Resources Institute (IPGRI)'s Board of Trustees from my great colleague Bill Tossell, who had championed the transformation of the International Board for Plant Genetic Resources (IBPGR) from a programme under the Food and Agriculture Organization of the UN (FAO) to an independent institution. My job now was to ensure continued support of the institute's top management under Geoff Hawtin's leadership to consolidate IPGRI as one of the CGIAR research centres.

My tenure coincided with the launch of the 'Diversity for Development' strategy, of which I was a staunch supporter. With my background as a dean and rector of research-heavy organizations, I knew it would be beneficial for IPGRI to get lab and field work closer to daily life and impact. I had always felt that grounding theories and politics in real experiences was a healthy exercise. It was not an easy task to transform the culture of a 'programme' into the culture of an international research centre. Many of the bureaucratic tendencies of a large international organization such as FAO were embedded in the traditions of IBPGR and now the freedom that followed independence had to be handled. On top of this, CGIAR strongly suggested to us that we should take on the additional responsibility of the Board of the International Network for the Improvement of Banana and Plantain (INIBAP) as well. The board was aware that in change — and particularly in mergers — there are high risks of losing out on programme productivity and impact while management focus is on staff, premises, rules and regulations.

We did it, but I had to leave the Chair to my dear colleague Wanda Collins at the request of FAO because I moved from my academic job in Denmark to the World Bank in order to take charge of higher education policy development there.

Staff members at FAO waiting to be allowed into the Board Meeting following the decision to definitively separate programmatically from FAO. 1993

Staff

Meet our Staff: Karol Araya, Qi Wei and Silvia Araujo de Lima

Karol Araya

2010–today; Finance Assistant, Costa Rica office

What I most appreciate about working at Bioversity International is diversity. I mean diversity in terms of our research, cultures, social interactions, management and experiences. Every day brings new learning.

Qi Wei

2001–today; Programme Assistant Beijing, China

Since I joined the Bioversity International family in 2001, one thing I have noticed is that many researchers from all kinds of organizations come to our office to ask for various publications such as newsletters, descriptors and technical guidelines for genebank management. This makes me realize that Bioversity's work on genetic conservation has had a *huge influence on Chinese scientists, and I'm very proud to be part of it. In recent years, Bioversity has been dedicated to using biodiversity to improve the wellbeing and incomes of farmers. This aligns with the pursuit of Chinese society.*

As Bioversity celebrates 45 years, it has become a prominent research organization in the world and I, together with my collegues, will keep up the work and strive for more achievements in the conservation and utilization of agrobiodiversity for a better life.

Silvia Araujo de Lima

Programme Assistant, Montpellier France

What I appreciate about Bioversity International's work today is the possibility to recognize the work of farmers and promote diversity, for example, through the Cocoa of Excellence Programme and the International Cocoa Awards. We also share best practices between partners and Bioversity to improve global food production systems and crop diversity conservation and exchange through MusaNet, CacaoNet and our research on agrobiodiversity.

PLANT

Making the most of crop collections

Despite successful campaigns collecting plant genetic resource and advances in their conservation methods, a Bioversity International (as IBPGR – International Board for Plant Genetic Resources) survey in the 1980s showed that breeders – the primary intended users of the conserved material – made little use of material from collections and had low awareness of collections and their value. Over the years, we have explored several ways to help breeders make more use of the increasing number of plant materials held in *ex situ* collections.

To make the most of this diversity, we acted to try and ensure that all the materials were well described and evaluated through the development of Descriptors, the information was widely available through information systems, and that new knowledge was generated and shared through crop networks.

'Core collections' were another way to stimulate use. Otto Frankel, one of the driving forces behind IBPGR, suggested as early as 1984 that core collections could make large collections of major crops more usable. These would consist of about 10% of the total *ex situ* collection, deliberately chosen to contain a high proportion of the diversity present in the whole collection. Staff would characterize and evaluate core collections, and make available larger quantities of seed. This would make it easier for breeders to choose and use material. Some experts feared the approach might lead to neglect of the rest of the collection and would not help when a desired trait was controlled by a single gene occurring only in a very few samples. Nonetheless, many genebank managers adopted the core collection approach, and it did prove a useful entry point, especially during the early application of molecular screening because it offered a manageable number of accessions while maximizing genetic diversity.

A third approach to encourage use was to promote efforts to broaden the genetic base of modern crop varieties, because a narrow genetic base makes a crop vulnerable to pests and diseases. IPGRI, with the Food and Agriculture Organization of the UN (FAO), organized several workshops on base broadening, leading to the publication of *Broadening the Genetic Base of Crop Production*. This publication presented a review of approaches with a compilation of case studies and examples that covered a range of different crop types, breeding systems and situations.

Surveys in the 1990s and then again in 2006 indicated that use of plant genetic resources depended not only their direct incorporation into breeding programmes but also research and evaluation. Other analyses, especially on the use of crop wild relatives, showed there were considerable differences between crops regarding which resources were used and how much use was made of them. For example, tomato breeders have made

Credit: Anita Sanchez/CIMMYT

substantial use of crop wild relatives, wheat breeders had a tradition of including traditional varieties and wild relatives in breeding programmes, while rice and maize breeders made much less use of such materials.

As we move into an era where production systems will need more genetic diversity to meet the challenges of climate change, our understanding of how to use these resources will become only more critical.

Toby Hodgkin

2011–today: Honorary Research Fellow

2009–2011: Principal Scientist

2007–2009: Director, Global Partnerships Programme

1996–2007: Principal Scientist

1989–1996: Research Officer and Director, Genetic Diversity Group

‘Germ-free’ germplasm

In the late 1980s, genebanks were starting to distribute material and had run into a problem: many seeds and other planting materials carry diseases that can spread to new areas if not carefully managed. For example the International Institute of Tropical Agriculture (IITA) was not allowed to distribute improved cassava material outside Nigeria for fear that it would spread cassava diseases. In addition, some CGIAR centres had been accused of distributing diseased material.

As a plant pathologist working for the Food and Agriculture Organization of the UN (FAO), I discussed this with Trevor Williams, then Director of the International Board for Plant Genetic Resources (IBPGR). He quickly established that this was indeed a problem and had spoken to the IBPGR Board. They hired me to head a germplasm health programme to undertake research on phytosanitary aspects of germplasm management. One of the first tasks was to develop a series of technical guidelines for the safe movement of germplasm. In collaboration with FAO, we brought technical experts together to build a consensus around the most reliable ways to detect specific pathogens and the best ways to clean up the material. The result was a series of about 25 publications for different crops, fruits and vegetables.

The project also identified gaps in our knowledge and set about filling them. For example, banana bunchy top disease had recently started to spread and cause concern, but nobody knew what caused it. IBPGR supported an Australian team that discovered the banana bunchy top virus. As a result, we have a diagnostic test so we can ensure that banana genetic resources in transit will not spread the disease, which is probably the most devastating banana viral disease.

Another outgrowth of this project was the formation of a Technical Working Group that brought together all the seed health experts from CGIAR genebanks. The Working Group allowed people to share experiences and information on the

Credit: H. Luhtasela-El Showk. Courtesy of Musarama, www.musarama.org

importance of ensuring that material was clean. It led to the situation today, where each of the 11 CGIAR genebanks has a germplasm health unit that ensures that the seeds and other materials that they distribute worldwide are healthy and pose no phytosanitary risk. The germplasm health units are continuing the work of developing diagnostic tests and methods to remove pathogens and pests from genetic resources.

IBPGR's early recognition of the need to develop guidelines for the safe movement of germplasm was vital to the success of CGIAR genebanks, and those guidelines are still getting many citations today.

Emile Frison

2003–2013: Director General

1995–2003: Director, International Network for the Improvement of Banana and Plantain

1992–1995: Regional Director for Europe

1987–1992: Germplasm Health Senior Scientist

System-wide Genetic Resources Programme

The System-wide Genetic Resources Programme (SGRP), which launched in 1994, was one of several initiatives intended to foster closer collaboration among the CGIAR centres. It emerged from a review of CGIAR, but had an additional impetus, which was the call for a CGIAR-wide response to the Convention on Biological Diversity and the *Global Plan of Action for Plant Genetic Resources for Food and Agriculture* of the Food and Agriculture Organization of the UN (FAO). SGRP encompassed the genetic resource activities of all centres and Bioversity International (as IPGRI – International Plant Genetic Resources Institute) was the convening centre.

In-Trust Agreements between centre genebanks and FAO effectively made the plant collections in CGIAR genebanks part of humanity's heritage in perpetuity. IPGRI, and in particular Geoff Hawtin, the Director General, was instrumental in shepherding the agreement through the Commission on Genetic Resources for Food and Agriculture and to the ultimate signing of the documents.

Once signed, it became important to live up to the In-Trust Agreements; IPGRI played a crucial part in that, through its coordination of SGRP. A key element was the System-wide Information Network for Genetic Resources (SINGER). This was a real breakthrough, bringing together information from each of the 11 centre genebanks into a single online repository. It created consistency for genebank information and promoted transparent access to genebank holdings. There had been nothing like it before; it brought enormous goodwill from countries and non-governmental organizations (NGOs), and was the foundation of today's Genesys.

In 1995, an SGRP-commissioned external review of the genebanks uncovered shortcomings in both operations and stable funding. SGRP obtained and managed two World Bank projects to upgrade all the centre genebanks as global public goods. SGRP also funded a study by the International Food Policy Research Institute, which assessed the costs and benefits of the genebanks and the amount needed to maintain funding in perpetuity. The upgrade and the costing study laid the foundations for the Crop Trust and the CGIAR Genebank Platform, which are carrying forward SGRP's work.

As coordinator of SGRP, IPGRI represented genetic resources in CGIAR and outside. We enabled CGIAR to speak with one voice at many different international meetings, and especially at the Conference of the Parties to the Convention on Biological Diversity.

Each centre provided relevant experts to speak on the topic at hand, including, for example, on livestock and fish. But they all spoke under a common CGIAR flag, which lent extra weight to their submissions.

This process continued in the negotiation of the International Treaty on Plant Genetic Resources for Food and Agriculture (Plant Treaty) and the Single Material Transfer Agreement that accompanied all genebank samples and embodied the principles of the In-Trust Agreements. SGRP could draw on the combined experience of the centres to work out what was possible and practicable. Its reports went to the CGIAR's Genetic Resources Policy Committee of external policy experts and NGOs. With their blessing, recommendations passed into the Plant Treaty negotiations.

The ultimate form of the Plant Treaty owes a lot to SGRP, which was recognized in 2006, shortly after it came into force, with the CGIAR's Partnership Award.

Jane Toll

2007–2014: Senior Project Manager, Crop Trust, Rome, Italy and Bonn, Germany

2005–2007: Director, Global Partnerships Programme

1995–2007: Coordinator of the CGIAR System-wide Genetic Resources Programme

1992–1995: Senior Scientist, Germplasm management

1987– 1992: Coordinator for West Africa, Niamey, Niger

1985–1987: Officer for the Great Lakes Region (Burundi, Rwanda and Zaire (DR Congo)) Gitega, Burundi

1980–1985: Collector and Consultant (Ethiopia, Italy, Kenya, Nigeria, Rwanda, Syria, Zimbabwe)

Descriptors: A common language for crops

Bioversity International (as IBPGR – the International Board for Plant Genetic Resources)'s support for genebanks around the world quickly ran into the difficulty of accurately identifying accessions. How could a breeder understand the differences between samples in a collection, to know which to use? How could genebanks understand whether they had duplicates or gaps in their collections? Very early on, IBPGR realized that the community needed a universal language to discuss the materials in genebank collections. This need was heightened by the spread of information systems, for which an internationally agreed format and universally understood language were essential.

The solution was to work with experts on the individual species to compile agreed descriptors. In 1977, IBPGR released the first descriptors for cultivated potato, developed with the International Potato Center and other partners. Although the concept, process and format would change over the years, after I took on the project in 1989, this was the first of a series of more than 150 descriptors published over the subsequent decades.

Descriptors present an easy-to-use, internationally agreed methodology for describing germplasm accessions, and are multi-stakeholder efforts involving many experts in different institutions and countries. For example, *Key Access and Utilization Descriptors for 22 Annex I Crops*, developed with CGIAR centres and partners, drew on 500 experts from 210 organizations in 85 countries.

The original lists identified a minimum number of characteristics to describe a crop. Over the years, the descriptors evolved. In 1990 they were relaunched as 'comprehensive lists' including extra information useful to breeders. From 1994 on, new sections on *in vitro*, cryopreservation, soil and environment, and ethnobotanical information were incorporated, as well as asterisks to indicate the essential information to record. *Descriptors for Genetic Marker Technologies* (2004) stipulated the minimum set needed to generate and exchange biochemical and molecular data that are standardized and replicable. In 2009, as Bioversity moved toward on-

farm conservation and use, *Descriptors for Farmers' Knowledge About Plants* allowed researchers to record farmers' preferences in a standardized way integrating biology and traditional knowledge. *Core Descriptors for In Situ Conservation of Crop Wild Relatives* (2013) describes a minimum set to document *in situ* material.

An outstanding descriptor worldwide is the Food and Agriculture Organization of the UN (FAO)/Bioversity International *Multi-Crop Passport Descriptors* (2001). It was last revised in 2015, confirming its validity after almost 15 years. This standard provides consistent passport vocabularies to use across crops, and is the backbone of databases, networks and global portals such as Genesys, EURISCO, the Global Information Portal of the International Treaty on Plant Genetic Resources for Food and Agriculture, and crop databases and ontologies.

Descriptors make it easier for partners to work together through more uniform documentation, and help users to select a wider range of germplasm. Though the concept is simple, the importance of the principles embodied in the descriptor lists cannot be overstated.

Adriana Alercia

1998–2015: Descriptor List Management and Capacity Strengthening

1994–1997: Germplasm Information Specialist, Descriptors

1989–1993: Consultant, Food and Agriculture Organization of the UN (FAO)/ International Board for Plant Genetic Resources


Ontologies: The science of connecting disconnected data

Effective communication requires a shared understanding of what words mean. When we study complex agricultural and food systems, we combine data from biophysical, socioeconomic and cultural spheres of investigation. But each sphere measures and collects data in different forms and in different ways, from household surveys to satellite images. Data are like words; we need to agree on what they mean to understand what they are communicating. That is where ontologies come in. An ontology is a formal representation of a domain of knowledge, where key concepts are defined, as well as the relationships that exist between those concepts. Ontologies in agriculture harmonize the variables that have been measured, by annotating the measurements in such a way as to make them comparable and interoperable.

In this way, ontologies enable data exchange across projects and across disciplines and facilitate their reuse by new projects. Not only is this more efficient, but it also opens the door to richer analyses, bringing in a wider sweep of information.

The Crop Ontology project began in 2008 to enable plant breeders to use an agreed system to describe details of crop traits and variables, such as time to fruiting or seed weight, which they measure in field assessments. It is a service now integrated into the Breeding Management System of the Integrated Breeding Platform, developed by the CGIAR Generation Challenge Programme, and provides a digital workbench for breeders to design breeding programmes and produce electronic fieldbooks for data collection. The result is improved data quality, which permits the meta-analysis of varieties' behaviour under different conditions.

The CGIAR Research Program on Climate Change, Agriculture and Food Security then supported Bioversity International and the International Center for Tropical Agriculture to integrate the Crop Ontology into 'AgTrials', a portal that compiles data on crop evaluation trials. AgTrials became the first online repository to use ontology concepts for dataset annotations. All CGIAR centres now use the ontology terms as keywords for dataset annotations in their public repositories, boosting the value of the datasets to a variety of investigators.

Over the years, working with CGIAR Research Centres and other partners, Bioversity has expanded the Crop Ontology from 8 to 27 species. While connecting the data, we also connected scientists, data managers, modellers and ontology experts into a community of practice in the CGIAR Platform for Big Data in Agriculture. The Crop Ontology is now a popular open-access resource not only for users of the Integrated Breeding Platform but also for other CGIAR crop information systems, and private and public research groups.

In ten years, the Crop Ontology has become a reference source and model for other ontology development efforts for agriculture. As part of the Big Data Platform, we developed the Agronomy Ontology for AGROFIMS, a global agronomy fieldbook and analytical application. This ontology applies to data beyond the crop itself, such as field management practices, weather and soil conditions. Now we are supporting an emerging ontology on agricultural household surveys and soon we will begin fish and livestock ontologies.

Elizabeth Arnaud

2008–today: Scientist, Ontology Project Principal Investigator

2008–2014: Diversity Informatics Team Leader

1997–2008: Musa Germplasm Information System Coordinator

« Ontologies serve as common standards for semantic integration of a large and growing corpus of plant genomics, phenomics and genetics data. The Planteome project (Planteome.org) has had a fruitful partnership with the Crop Ontology Project for several years. The mapping of Crop Ontology traits with the reference species-neutral Trait Ontology of Planteome has created a semantic framework that connects genotype to phenotype data and unlocks the search of annotated trait data across species that are of interest for breeding and comparative genomics.»

Pankaj Jaiswal, Associate Professor, Department of Botany and Plant Pathology at Oregon State University

Lead Investigator of the NSF-funded Planteome.org reference ontology project (NSF grant IOS:1340112) and Co-lead of Gramene Database Project on Exploring Function through Comparative Genomics and Network Analysis

Genesys: Genebank data at your fingertips

In the beginning there were SINGER, EURISCO and GRIN*. That's how the genebanks of the CGIAR Centres, the countries in the European plant genetic resources network, and the United States Department of Agriculture, respectively, shared information on their collections online, from the early 1990s. It was great: passport data on millions of accessions, in dozens of different genebanks, at your fingertips. For a crop of interest, a researcher or breeder could immediately know where samples originated, and where they were housed now. But it could be even greater. If you were interested in wheat from Afghanistan, say, you needed to navigate three entirely separate websites, each with a different, independent database behind it. We all felt we could do better.

That's the genesis of Genesys. Bring the data from these three online systems together into one database, to be accessed and queried from a single portal. One search query for wheat from Afghanistan, rather than three. Or indeed more. The Big Three was always supposed to be just the start. Others would come, we felt sure. And we were right.

I had just started working at the Crop Trust, under Jane Toll. Our job was to implement a huge project funded by the Bill & Melinda Gates Foundation. One component was Genesys, though it wasn't called that at the time. We went through a number of names. My favourite was ALIS: the Accession-Level Information System. Bioversity International was a key player, with its invaluable experience of developing SINGER and EURISCO. The idea was to bring their data together and expand the result to encompass GRIN too.

So, starting in 2008, Bioversity's database people – Samy Gaiji, Elizabeth Arnaud and Milko Škofic – worked with the Crop Trust to put together a plan. Bioversity hired a project manager, Michael Mackay, and a programmer, Fawzy Nawar. Within a couple of years, they had a website up and running, from which you could query the Big Three. Eventually, a few

*SINGER: System-wide Information Network for Genetic Resources; EURISCO: a search catalogue providing information about ex situ plant collections maintained in Europe and beyond; GRIN: Germplasm Resources Information Network

Credit: Neil Palmer/Crop Trust

more years down the road, this replaced SINGER. More genebanks came on board. Genesys now provides access to passport information on 3,889,117 accessions in 459 institutes and, starting this year, to 79 characterization and evaluation datasets too. It gets about 4,000 visits a month. The portal itself has gone through a couple of different changes in look, but what we did back in 2008 was really the start of something new. Hence the name.

Luigi Guarino

2007–today: Science Coordinator, The Crop Trust and since 2016 Director of Science and Programs

2002–2006: Secretariat of the Pacific Community in Fiji

1997–2002: Genetic Diversity Scientist, Latin American and Caribbean Office, Cali, Colombia, IPGRI

1992-1996: Genetic Diversity Scientist, IBPGR/IPGRI, sub-Saharan office, Nairobi, Kenya

1992: Germplasm Collector, IBPGR, Cyprus

1984–1987: Consultant, FAO and IBPGR

Know your banana: The *Musa* Germplasm Information System

The *Musa* Germplasm Information System (MGIS) is rooted deep in the history of the International Network for the Improvement of Banana and Plantain (INIBAP) and continues to grow in Bioversity International. The *Musa* conservation group, as it was then, developed the concept of an information system to bring together the information scattered across multiple formats (books, articles, collecting mission reports, trial reports etc.) and deal with the lack of standardized terminology to identify, describe and evaluate bananas. INIBAP and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) jointly presented the idea to a workshop in Leuven, Belgium, in December 1989.

The development of computer databases offered an opportunity to create a Central Germplasm Information System to tackle those issues. In late 1993, Canada's International Development Research Centre (IDRC) financed a 3-year project to develop the first database. MGIS version 1.0 was released as a standalone desktop application in 1996 and included the banana descriptors that had just been published. A year later, INIBAP and CIRAD jointly organized the first MGIS training workshop at a CIRAD research station in Neufchâteau, Guadeloupe. In this way, ten curators of the major *Musa* collections were trained on the MGIS methodology and tested the MGIS software and database before we distributed it more widely.

The use of standardized data facilitated the release of two *Musalogue* publications – catalogues of *Musa* diversity – in 1997 and 2001. In 2003, the data from MGIS moved online so that anyone with access to the internet could obtain information about specific banana accessions, including passport and characterization data. The MGIS website also offered online access to the collection at the Bioversity International *Musa* Germplasm Transit Centre (ITC).

Since then, we have actively developed and maintained MGIS to include more partners' collections (through data sharing agreements) and to diversify its content with genetic and phenotype information and literature. For example, we have enriched the materials maintained in the ITC *in vitro* collection by supplementing them with characterization data and photos captured during field verification, an ongoing check of the collection's integrity. Scientists at the ITC analyze each new accession for basic genetic information, and link this information through MGIS. And since 2012, the online ordering system in MGIS handles requests to the ITC for material.

Bioversity continues to distribute a standalone version, which includes a mobile application called MusaTab that supports the capture of high-quality data in field collections. These tools can then automatically update the MGIS database and pave the way for a broader use of the dataset, for example to help identify

varieties with MusaID, another mobile application developed by Bioversity and CIRAD.

After 20 years of existence, MGIS has evolved and adapted to enrich its core dataset while benefiting from other data types, standards and software technologies to provide a better user experience. It also serves as a key tool for knowledge dissemination during MusaNet regional workshops held in Asia, Africa and Latin America. MGIS provides the best picture of *Musa* diversity in the world, vital for the conservation and use of that diversity.

Max Ruas

2008–today: Information System Analyst, MGIS Manager
2005–2007: Database Manager
2000–2004: IT Manager

"MGIS is an excellent system for documentation and sharing information on Musa germplasm. I always consult the MGIS to clarify doubts about the germplasm of Musa. MGIS … gathers a huge volume of information about Musa germplasm, connecting curators from different institutions and encouraging not only conservation, but also the use of Musa genetic resources."

Janay Almeida dos Santos Serejo
Researcher, Plant Breeding and Cell Biology
Curator of the Musa Germplasm Collection
Embrapa Cassava and Fruits

Unravelling the banana genome

In 2001, only a few months after the first plant genome was fully sequenced, Bioversity International (as IPGRI – the International Plant Genetic Resources Institute) set up a consortium of partners to sequence the banana genome. It took about ten years for the 'Global *Musa* Genomics Consortium', which we coordinated, to achieve its dream with the release of the first reference genome in the important journal *Nature* in 2012. The reference genome was made possible by progressive generations of key genomic resources and the actions of the community to raise the importance of the crop.

Beyond providing an extremely valuable tool to improve banana varieties, the sequence allows researchers to study the evolution of the *Musa* genome. This research has resulted in a large number of citations and high-volume traffic to its associated scientific databases, including the 'Banana Genome Hub', which is maintained on the South Green Bioinformatics Platform. We have organized community training courses with national partners from Asia, Europe, Latin America and sub-Saharan Africa to make sure that this information can be efficiently used.

The availability of the banana genome sequence, along with the increased capabilities of next-generation sequencing technologies, provides a unique opportunity to unlock the potential of the genetic diversity stored at the Bioversity International *Musa* Germplasm Transit Centre (ITC). With support from the CGIAR Research Program on Roots, Tubers and Bananas, one-third of the ITC collection is being analyzed with high-throughput genotyping methods. This has enabled us, for instance, to study the genetic bases of sterility and parthenocarpy (forming fruit without the need for pollination) in banana. Moreover, since 2012, several other genomes of wild banana species have been fully sequenced,

and efforts to sequence more challenging banana genomes are underway.

Large-scale genome data mining is now an integral part of Bioversity's agenda, with the establishment of a dedicated unit for the analysis and management of banana genomic information. We continue to improve our understanding by exploiting the genetic variation of the crop's diversity, whether maintained in genebanks, on farm or in natural habitats, and as such contribute to enhancing the productivity, sustainability and resilience of banana cultivars and their agricultural systems.

Mathieu Rouard

2013–today: Lead Scientist, Bioinformatics Unit

2009–2012: Scientist, Genomics and Bioinformatics

2004–2008: Programme Specialist, Bioinformatics

The Genetic Resources Policy Initiative

The Genetic Resources Policy Initiative (GRPI) was created to support national level, multi-stakeholder dialogues about genetic resource policies. GRPI was inspired by earlier international multi-stakeholder dialogues in which Bioversity International (as IPGRI – the International Plant Genetic Resources Institute) had been involved, namely the Keystone Dialogues (1988–1991) and the Crucible Group Rounds 1 and 2 (1993–1994; 1998–2000). Having experienced the benefits of these international dialogues, the natural next step for the organization was to sponsor similar engagements at the national level.

In GRPI Phase 1 (2002–2006) we piloted our '3M methodology' – multi-stakeholder, multidisciplinary, multi-sectoral – to engage a wide range of individuals and organizations in project governance. We also conducted national surveys and dialogues to prioritize policy issues for consideration to inform the actual policies developed by the project including seed policies, *sui generis* intellectual property rights, access and benefit-sharing policies and public investment in agricultural research.

By the time we launched GRPI Phase 2 (2011–2017), the International Treaty on Plant Genetic Resources for Food and Agriculture (Plant Treaty) was in force, and, in 2006, its Governing Body had adopted the Standard Material Transfer Agreement. The international components for a global policy framework were finally in place; all that was missing was national level implementation. So GRPI 2 focused its '3M' methodology on helping countries to develop national implementing systems that responded to their particular needs.

The project supported national '3M' teams in eight countries – Bhutan, Burkina Faso, Costa Rica, Côte d'Ivoire, Guatemala, Nepal, Rwanda and Uganda. These teams convened national consultations and dialogues and conducted policy research on key issues: the structure and influence of policy actor networks; germplasm flows in, out and within the country; institutional challenges to community crop diversity management; and technology transfer needs. They then made use of their consultation and research results to design customized policies. After the Nagoya Protocol on Access and Benefit Sharing came into force in 2014, GRPI piloted several activities to forge links with stakeholders working on implementation of the Protocol.

Bioversity and the project partners have published numerous books, journal articles, policy briefs and decision-making tools based on their work in the GRPI project. By 2017, all partner countries had developed strategies to participate in the Multilateral System established by the

Plant Treaty, including a draft portfolio of complementary policies and laws to implement it. By the end of the project, many of those policies had been formally approved by the requisite governmental bodies.

Bioversity is launching GRPI Phase 3 in 2019 focusing on using crop genetic diversity to adapt agricultural production systems to climatic changes, accessing materials through the Plant Treaty's Multilateral System and/or subject to national laws implementing the Nagoya Protocol.

Michael Halewood

2001- today Head of the Policy Unit

"The rich set of research outputs generated from project activities implemented is clear evidence of significant achievements made under the GRPI2 project, providing valuable inputs in influencing the agriculture research and development community as well as the policymakers and planner community on the other hand. It is obvious that many countries are using project outputs as models or prototypes for country-specific adaptations (e.g. crop domestication publications, community seedbanking, policy briefs on networking analysis, etc.)."

Godfrey Mwila, Deputy Director, Zambia Agricultural Research Services, and Julian Gonsalves, Senior Programme Adviser, International Institute of Rural Reconstruction, 2017, Final External Review of the GRPI2 Project

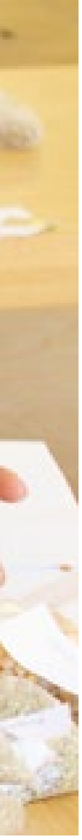
Resilient seed systems

Farmers in developing countries face unprecedented challenges to deal with changing climates and related crop management problems. Erratic and less predictable rainfall, and in some regions warmer temperatures and higher humidity, longer hot spells and recurring droughts are expected to become more frequent. All these changes seriously affect how farmers manage their crops to maintain production. Current seed systems do not serve their needs.

In recent years, Bioversity International has piloted various initiatives in more than 20 countries to support novel configurations of actors operating at farm, community, national and international levels to develop resilient seed systems. Such seed systems are the basis of sustainable food systems and healthy diets for several reasons. They rely on the ability of participants to adapt to stresses and changes by taking advantage of the combined knowledge and experience of all the participants and institutions. Furthermore, they respond to the needs of the farmers in their diverse farming operations, recognizing the key role of women as seed custodians and entrepreneurs. Resilient seed systems can benefit from policies and laws that support a variety of options for business models around the supply of seeds.

We carried out different types of activity, depending on each country's existing seed systems. For example, we promoted participatory characterization of varieties, getting farmers and scientists together to evaluate crops and varieties. That sometimes included identifying and testing varieties promising for climate change adaptation. Community seedbanks are important and can serve many functions, so they were a focus of support. We connected community seedbanks to national genebanks, where appropriate, and also helped communities build seed-based enterprises. A key element is to ensure that communities benefit from access to their genetic resources, which often included lobbying for alternative national systems for variety registration and seed certification, and also involved working with international agreements for access and benefit sharing, such as the International Treaty on Plant Genetic Resources for Food and Agriculture.

Among the results of these activities are a greater capacity of smallholders and other stakeholders to produce quality seed of diverse varieties that meet farmers' preferences and needs. At a local



level, many new community seedbanks were established and linked to farmer organizations and women's groups for seed production. Seed systems have been diversified, increasing accessibility to seed and improving seed and food security. National partners have used research results to influence national seed policies in some countries, such as Bolivia, Nepal and Uganda, where farmers' organizations can now produce, package and sell quality-declared seed. Bioversity International and national partners have used the project's results in global policy debates on the importance of agrobiodiversity for sustainable agriculture, the fair and equitable sharing of benefits derived from the use of plant genetic resources and related knowledge, and the effective implementation of Farmers' Rights.

Ronnie Vernooy

2011–today: Genetic Resources Policy Specialist

"Investing in alternative crops for building resilience, adaptation and food security is a good strategy for ensuring food and nutrition security and climate change adaptation. Resilient seed systems research builds on indigenous resilient agricultural practices. Women farmers are key players in this process. The critical questions are: What are the barriers to sharing indigenous knowledge between and among communities? What are the limits of farmers' resilience and adaptation capacities? How can we assist them to become more resilient?"

Andrew Mushita
Director Community Technology Development Trust
Harare, Zimbabwe

ECPGR: The European Cooperative Programme for Plant Genetic Resources

In 1980, the Food and Agriculture Organization of the UN with the UN Development Programme identified a need and opportunity to create a mutually beneficial system for the maintenance of comprehensive, well-documented collections of crop genetic resources in Europe. This system would also encourage the more effective use of plant genetic resources in plant breeding. The European Cooperative Programme for Plant Genetic Resources (ECPGR) was the result. In 1983, the countries requested Bioversity International (as IBPGR – International Board for Plant Genetic Resources) to coordinate it.

Over the years, we have created 22 crop and thematic Working Groups, which actively exchange information and project ideas and forge new partnerships. Forty-three European countries are now cooperating. This meant, in 2003, we could establish the European Search Catalogue for Plant Genetic Resources (EURISCO), which documents 2 million accessions conserved by more than 370 institutions throughout Europe.

The European Collection, which was established in 2011 under the European Genebank Integrated System (AEGIS), is a decentralized collection of unique accessions maintained under formal long-term agreements, at high-quality conservation standards, made available based on internationally agreed principles.

Our most recent innovation is a European Evaluation Network (EVA), established in 2018 to provide a joint evaluation of accessions in the European Collection across multiple environments, making practical and systematic use of the genetic diversity conserved. Initially we will be evaluating resistance traits to crop pathogens.

As understanding has grown of the complementary roles of conservation in genebanks, in the wild and on farm, we have launched initiatives to conserve and use crop wild relatives in the wild and to promote on-farm conservation and management of the diversity of European plant genetic resources for food and agriculture.

ECPGR has increased the transfer of knowledge and collaboration across the region. The most visible achievements (EURISCO, AEGIS, EVA and the *in situ* concepts), testify to the possibility of building regional infrastructures or frameworks that could offer examples to other regions.

Collaborative action to document the European genebank accessions means that information on the largest set of diversity currently included in the Global Information System is now available online. The next challenge to improve global food security and address the problems brought by climate change will be to discover exactly which type of useful traits are contained in the collection and effectively use them. *In situ* and on-farm strategies are multiplying efforts to protect and manage diversity in the fields and the creation of the first network of crop wild relative genetic reserves is under way.

Lorenzo Maggioni

1999–today: Scientist, ECPGR Coordinator/ Secretary

1996–1999: Associate Scientist, ECPGR Coordinator

"The objectives of ECPGR are very important because the national initiatives display a very heterogeneous level of efficiency for safeguarding plant genetic resources. ECPGR helps spread this efficiency upwards through international collaboration and dialogue between crop curators of European countries, and via its technical publications of outstanding value for people in charge of plant genetic resources."

Partner responding to a questionnaire for the ECPGR External Review 2010

Banana research networks for innovation

The International Network for the Improvement of Banana and Plantain (INIBAP), over the course of its existence, has set up several networks to support work on bananas. These started with a research network in each of the four banana-producing regions where INIBAP had an office: the Banana Research and Development Network for Latin America and the Caribbean (MUSALAC), the Banana Research Network for East and Southern Africa (BARNESA), the Banana Asia-Pacific Network (BAPNET), and the regional network for West and Central Africa (MUSACO – now called Innovate Plantain). The regional networks helped national partner organizations to identify and meet challenges to banana production in their respective regions.

In 1997, INIBAP and the World Bank established the 'ProMusa' global programme, to accelerate the impact of banana improvement efforts by increasing interactions between pathologists and the world's banana breeders. The programme had five interlinked thematic working groups (genetic improvement, Fusarium wilt, Mycosphaerella leaf spot diseases, nematodes and viruses). In 2001, INIBAP was also instrumental in the creation of the Global *Musa* Genomics Consortium, again to help speed up the development of disease- and pest-resistant bananas.

When INIBAP and the International Plant Genetic Resources Institute (IPGRI) entered a new phase in 2006 with the adoption of a common name, Bioversity International, the networks also adapted to the new realities. The regional banana research networks, for example, were redeployed as innovation platforms.

As for ProMusa, it opened up its membership to all individuals interested in bananas and reinvented itself as a platform for sharing, examining and debating research results and knowledge on bananas. The network is currently supported by a website (www.promusa.org) where people can keep up-to-date with what is happening around the world. This is done through a news and blogs section, a community bulletin board, and *Musapedia*, an online compendium of knowledge on the crop that tries to make sense of the vast amount of material generated by the scientific enterprise through concise and clearly written texts. In addition to being recognized as a trustworthy source of information, ProMusa is increasingly called upon to

sort the facts from the hype circulating on social media.

The network also organizes, in association with the International Society for Horticultural Science, symposia that are later reported in proceedings. When not meeting face-to-face, the more than 900 ProMusa members stay in touch through the network's mailing list.

In 2011 we added a new network, 'MusaNet' (www.musanet.org), to provide a collaborative framework for the implementation of the 2006 *Musa* conservation strategy, which network members updated in 2016. The network's structure comprises a Coordinating Secretariat, an Expert Committee (in which ProMusa and the regional banana networks are represented) and five thematic groups: diversity, evaluation, information and documentation, conservation, and genomics.

As the then Director of INIBAP, Richard Markham, noted in 2006, "banana researchers are perhaps not the scattered and beleaguered band that they were 20 years ago. And perhaps INIBAP can take some of the credit for linking them together into a more potent force for constructive change".

The Banana Group

Strengthening capacity

From its inception, Bioversity International (as IBPGR – the International Board for Plant Genetic Resources and then IPGRI – the International Plant Genetic Resources Institute) pursued the objective to 'promote training at all levels'. Its early emphasis was on the academic level, codifying the new science of plant genetic resource management into postgraduate curricula to develop a new cadre of national scientists who would take responsibility for maintaining their country's and region's plant genetic resources. Bioversity and partners worked closely with universities around the world, most notably the University of Birmingham in the UK, to develop teaching, curricula and materials for degree programmes. Eventually these programmes developed adequate core capacity to be self-funded and managed independently. Graduates assumed positions of responsibility managing national seedbanks and *in vitro* collections, and coordinating crop and plant genetic resource networks.

Formal academic programmes were complemented by competitive North-South research fellowships, internships and mentoring arrangements that enabled young scientists to work with Bioversity's research teams or carry out research at our partner institutes. Bioversity's self-funded annual Vavilov-Frankel Fellowship and Abdou Salam Ouedrago Forestry Fellowship schemes were two examples. In addition, Bioversity established an international fellowship programme for training at the PhD level in molecular biology in Wuhan, China with the Huazhong Agricultural University and collaborated with the Scuola Sant'Anna in Pisa, Italy on a government-funded international PhD fellowship programme in agrobiodiversity.

In parallel, Bioversity used, and still uses, a multiplier approach to reach a broader audience and strengthen the capacity of partners, practitioners and trainers within projects and networks at the local, national and regional level. This involves transforming its science outputs into decision-support tools, good-practice guidelines, training manuals, experiential learning videos, and e-learning courses. The purpose is to move research into application. Topics include: the implementation of the International Treaty on Plant Genetic Resources for Food and Agriculture; pre-breeding for effective use of genetic diversity; seed handling in genebanks; collecting plant genetic diversity; crop

wild relatives; using molecular marker technology for plant genetic diversity; neglected and underutilized species; forest genetic resources; and payment for agrobiodiversity conservation services.

From 2012, there was a shift away from cross-cutting, free-standing courses and training materials and from national programme strengthening and network support, as capacity development became decentralized and embedded in the precise impact pathways of CGIAR and other research programmes.

One outcome of note was the translation and uptake of Bioversity's training module on Law and Policy of Relevance to Plant Genetic Resources into the curriculum of the MSc Programme on Plant Genetic Resources at the University of the Philippines, Los Baños, in order to train graduate students to negotiate their country's response to its implementation. By the early 2000s several national plant genetic resource programmes in countries like China, Korea, Taiwan and India implemented their own self-funded international courses on genetic resource management and molecular technologies for plant breeding, adapting curricular materials originally developed by Bioversity. The existence of functioning genebanks in countries around the world using manuals and guidelines and tools developed by Bioversity in collaboration with its partners is yet another example of a difference made.

Elizabeth Doupé Goldberg

2013–today: Honorary Fellow

2012–2013: Head, Knowledge Management & Capacity Strengthening Unit

2006–2012: Head, Capacity Development Unit

1999–2005: Head, Documentation, Information and Training Grou

Cultivating plant genetic resource leaders

Professor Jack (John Gregory) Hawkes founded the MSc in Conservation and Utilization of Plant Genetic Resources in the Department of Botany at the University of Birmingham in September 1969, following a request for such a course from the Food and Agriculture Organization of the UN (FAO). The leading figures of plant genetic resources at that time, Sir Otto Frankel, Jack Harlan, Erna Bennett and Jack, recognized that the skills shortage in plant genetic resources was limiting the conservation and use of plant genetic diversity. They particularly noted the lack of trained plant genetic resource scientists in developing countries, where the bulk of plant genetic resources diversity is found and where activities were necessarily focused.

Their initial thought was that an MSc level course would run for ten years before training all the required scientists, but this proved short-sighted as the need to train plant genetic resource experts continues today. The course initially provided training in crop diversity, germplasm collection, seed technology and tissue culture for gene preservation, as well as aspects of plant breeding and biotechnology leading to the effective utilization of plant genes. However, the course outlived expectations and evolved over the years, adding modules in informatics, genomics, conservation planning and *in situ*/on-farm conservation, with field work in the Mediterranean; and associated short continuing professional development courses and more general plant conservation courses.

The courses were always collaborative and involved annual contributions from Bioversity International and FAO, but also from UK partners like the Millennium Seed Bank Kew, Horticultural Research International, Welsh Plant Breeding Institute, John Innes Centre, Garden Organic and commercial plant breeders. The course was originally sponsored by Bioversity International (as IBPGR – the International Board for Plant Genetic Resources), FAO and the World Bank, then latterly by the Southern African Development Community and the European Social Fund. The central MSc closed in 2010 as sponsorship declined, not because of a lack of students nor a lack of the requirement for master's level plant genetic resources training – there is still a requirement for such international plant genetic resources MSc level training today.

The Conservation and Utilization of Plant Genetic Resources related courses trained over 1,600 professional plant genetic resources staff from 94 countries, primarily in the developing world. Graduates went on to fill key positions at mid- to senior level in plant genetic resources conservation, including numerous genebank managers across the globe and CGIAR Centres, while others moved into aspects of genetic resources or breeding research. The majority still play a role, which is as crucial today as it was

in late 1960s, in ensuring that plant genes throughout the world are available and utilized for maintaining food security and benefits for humankind.

Nigel Maxted

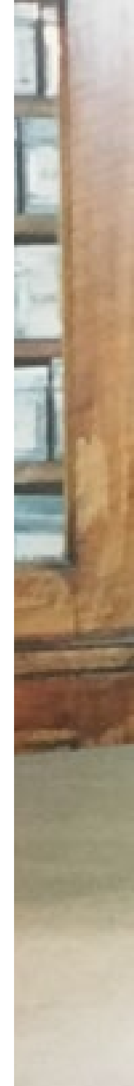
2016–today: Senior Advisor, Bioversity International

1991–today: Senior Lecturer in Genetic Conservation, University of Birmingham

1984: Plant Collector, FAO/IBPGR

"In 1986, my employer – the government through the Ministry of Agriculture – sent me and another colleague on the Birmingham MSc to acquire the technical capacity to develop and implement a national programme for the conservation of plant genetic resources for food and agriculture in Zambia. Upon my return, they tasked me with developing and implementing our National Plant Genetic Resources Programme. This culminated in establishing a national genebank and country-wide collection of plant genetic resources – to date holding slightly over 6,000 germplasm samples. I represented my government in the negotiations leading to the adoption of the International Treaty on Plant Genetic Resources for Food and Agriculture (Plant Treaty) in 2001. My involvement in the implementation of the Plant Treaty culminated in my being elected Chair of the Second Governing Body session in 2007. At the time I completed the training there were no other qualified individuals within the South African Development Community (SADC) so I was a key resource at the sub-regional level, especially when establishing the SADC Plant Genetic Resources Network Programme."

GODFREY MWILA
Deputy Director, Technical Services, Zambia Agriculture Research Institute



The Vavilov-Frankel Fellowship: Experiences of a Fellow

The Vavilov-Frankel Fellowships Programme was established by the Bioversity International Board of Trustees (as IPGRI – the International Plant Genetic Resources Institute) to commemorate the unique contributions to plant science by Nikolai Vavilov and Sir Otto Frankel. The first two Fellowships were awarded in 1993 to Igor Loskutov from Russia and Robin Pistorius from the Netherlands.

In 1993, Igor Loskutov and I began our fellowships to examine and record the work of scientists in the plant genetic resources community. My research encompassed a historical survey on the actions, politics and debates surrounding the early efforts of scientists to establish global governance on agrobiodiversity.

My research discussed how plant genetic resource conservation became a global issue, detailing collecting and introduction activities during the period 1900 to the 1960s. Most fascinating was researching the emergence of *ex situ* conservation as a predominant model, following the 1967 Food and Agriculture Organization of the UN (FAO)/ International Biological Programme Technical Conference, the development of breeding and conservation strategies and establishing a global *ex situ* conservation network during the 1970s. I documented and explored the development of conservation and use of genetic resources in two political arenas: the 'genetic resources conservation issue' vs. the 'agrobiodiversity use issue', a tension that has remained to this day. The genetic resources conservation issue is the philosophy that crop genetic resources is mainly a source of traits, while the agrobiodiversity issue sees crop biodiversity as a component of natural and managed systems, which include humans too.

The emergence of the theme of intellectual property rights (which would end up in the establishment of the International

Treaty on Plant Genetic Resources for Food and Agriculture), was dramatic in the world of plant genetic resource conservation. Who did resources belong to? Is it better to keep them *in situ* where they originally grew? How do you guarantee rights if they are housed in a genebank in another country? I examined the arguments for and against *in situ* and *ex situ* conservation, and their implications for conservation strategies – again arguments that are still very relevant more than 20 years later.

The research took double the work and time that I had anticipated but allowed me to have treasured in-depth conversations with the founding thought-leaders of early agrobiodiversity governance, Sir Otto Frankel in Australia and Erna Bennett.

For me personally the fellowship gave me a unique opportunity to access the inner workings of the politics and governance of global agricultural biodiversity conservation. Today, about 25 years later, the work in 1993 still forms a silver line in my career development focusing on advisory work and academic teaching on environmental and agricultural issues.

Robin Pistorius

2003: Consultant, Facts of Life

2010: Lecturer, Department of Political Science, University of Amsterdam

1993: Vavilov-Frankel Research Fellow

From Rome to the world: spreading the word about agricultural biodiversity

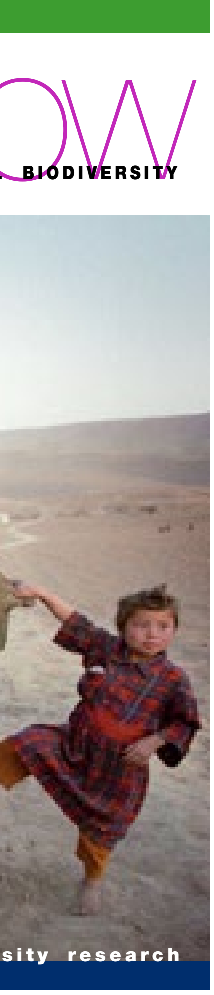
Bioversity International (as IBPGR – the International Board for Plant Genetic Resources) was the first CGIAR Centre to realize the importance of communicating research results and their impacts to a range of stakeholders. In 1987, I was hired to establish an external communications office for the institute – the first full-time public awareness person in CGIAR. As Chair of the CGIAR Public Awareness Association (1998–2002), I led a large number of system-level communications initiatives.

At IBPGR, my job was to provide strategic and tactical support on media, donor relations and public outreach. One of the first things we did was produce *Last Plant Standing*, a four-part documentary series on plant genetic resources which was broadcast on national television around the world, including national networks in the UK, Canada and Japan.

In 1990, we established *Geneflow*, an annual magazine to promote awareness of the importance of agricultural biodiversity and the role it plays in improving people's lives and livelihoods. For close to 20 years, this multi-award-winning publication carried stories about local, national, regional and international efforts to conserve and use agricultural biodiversity around the world.

1992 welcomed the Rio Earth Summit, with Bioversity International (as IBPGR – International Board for Plant Genetic Resources) representing CGIAR with presentations, side events and displays at the NGO Forum and the Summit itself. The Convention on Biological Diversity (CBD) opened for signature in Rio, and Bioversity has represented CGIAR at every meeting of the CBD Conference of the Parties ever since. Ten years later, we represented the CGIAR Research Centres at the World Summit on Sustainable Development in Johannesburg, where the implementation of the Millennium Goals was being discussed. There, we helped to put agriculture on the agenda.

Efforts to fund the Crop Trust started at the Johannesburg summit, with the ambitious aim to establish a long-term financing mechanism to support the world's genebanks. Our work cranked up a gear as we led a huge public awareness campaign to alert the world to the risks of losing genetic diversity. We took advantage of our participation in the World Summit to launch, with the Food



and Agriculture Organization of the UN, our successful funding campaign.

In 2008, Bioversity established *Diversity for Life*, a global communications campaign targeting policymakers, schools and the media. Featuring partners such as the International Fund for Agricultural Development, Slow Food and the Convention on Biological Diversity, the campaign developed educational materials and established home gardens in schools all over the world. It culminated in *La Settimana della Biodiversità*, a week-long festival in Rome that included a concert, a film festival, more than 80 speakers and activities for children.

At its height, the public awareness unit consisted of a team of nine staff operating out of five regional offices. Together, we produced hundreds of booklets, posters, magazines, web pages, fact sheets and exhibits. We trained more than 150 colleagues and national programme scientists in media relations and public awareness. We can be proud of our initiatives and of our legacy.

Ruth Raymond

2009–2010: Communications Manager, Regions and Programmes

2000–2009: Head, Public Awareness Unit

2000–2006: Campaign Coordinator and Assistant Executive Secretary, Crop Trust

1987–1999: Public Awareness Officer/Senior Scientist

Credit: Mulele Sibeso

Traditional knowledge: recognizing farmers as equal knowledge-holders

Farmers hold unique knowledge about their crops and how best to manage them. Eager scientists would often interview indigenous and traditional farmers and extract information about the unique properties of crops, or their time-tested sustainable management practices. The scientist would get the credit for the paper as the farmer was only acknowledged, not cited. When knowledge was not documented, every time a scientist visited a farmer they would repeat the same question and deprive the farmer of time in the field. A method for documentation and sharing by farmers for other farmers and scientists was needed.

This was the problem we addressed when I joined Bioversity International (as IPGRI – the International Plant Genetic Resources Institute) in 1993. The HQ documentation team were exploring how to store traditional knowledge as additional information linked to accessions in genebanks. The oral customs of traditional knowledge were difficult to convert into data.

In 1997, working with Zhang Zongwen from the Beijing office we came up with the concept of the *Traditional Knowledge Journal* (TKJ) which was then tested in Yunnan, China and in Kenya. In 2001, the Sarawak Biodiversity Centre launched their traditional knowledge programme, collaborating with IPGRI. We brought in a farmer from Kenya and a scientist from China for a seminar with Malaysian indigenous community representatives. The idea that a regular farmer from Kenya was able to document his community's traditional knowledge captured the imagination of the Sarawak communities and empowered them to do the same. The Sarawak Biodiversity Centre adopted the TKJ concept and fine-tuned it into a framework for their regular activities with traditional communities, which included regular traditional knowledge workshops where community members make presentations to share their experiences in documentation as well as knowledge.

The TKJ concept was derived from the scientific journal system where knowledge providers are recognized and cited. Enabling the citation of farmers' knowledge in the same approach as scientific journals allowed communities to trace from the citations who had used their knowledge and to make benefit-sharing claims where applicable.

Scientific papers in a journal tend to have a formal structure, however, that did not match the oral tradition, which followed a storyline. To maintain the farmer's approach of knowledge sharing, we would ask only "What would you like to tell your grandchildren about this plant?" We recorded the knowledge on audiocassette tapes (which we called the 'farmer's paper' and can be cited). This allowed their children and scientists to access the knowledge and the language used, which oftentimes was also endangered. Community gardens of useful plants sprouted in Sarawak villages where traditional knowledge documentation was implemented by the Sarawak Biodiversity Centre to allow children accessing the knowledge, to learn about the plants using the audiotapes.

In 1995 when we developed this methodology, it was very innovative and part of a portfolio of participatory approaches, developed and adopted by IPGRI, which seek to put farmers first, prioritizing their needs and knowledge in research. The methodology was documented in the second edition of the handbook *Collecting Plant Genetic Diversity: Technical Guidelines*, published in 2011.

Paul Quek

2012–2018: Honorary Fellow

1998–2011: Scientist Documentation information

1993–1997: Documentation Information Specialist

Seeds for Needs: Ethiopia

In the past 50 years, significant genetic diversity has been lost from production systems, largely replaced with commercial varieties. However, the need for genetic diversity to adapt to climate change is higher than ever.

'Seeds for Needs' is a Bioversity International-led initiative that started by asking whether any plant genetic resources hidden in national genebanks could be useful to smallholder farmers facing climate changes. We surmised that the current climate of one place might be similar to the predicted future climate of a different place. If so, plant varieties adapted to the first place might be suitable for the second.

In 14 countries across Africa, Asia and Central America, Bioversity International researchers and partners explored genebank accessions for samples potentially adapted to future climates, and worked with more than 14,000 farmers to evaluate them.

In Ethiopia, farmers in two different communities – Melfa and Workaye – grew and evaluated more than 400 varieties of durum wheat: 373 farmer varieties and 27 commercial varieties. We asked men and women farmers to capture the different characteristics they judged important. Most of the top performers were farmers' varieties, although not necessarily ones already known to the two communities. We gave seeds of the top 20 varieties to 400 farmers to test under their own conditions, as citizen scientists.

Three especially promising varieties emerged from the trials, two of which were accepted for registration by the Ethiopian variety release committee. That means they can officially be sold and made available more widely. More importantly, it shows that farmers' varieties can be the best option available to farmers. In the release process the seeds are compared with standard commercial checks, as only varieties that are performing better than the standard check can be released.

The farmer partners called these two varieties 'Stable' and 'We have it back' to reflect that the first yielded well under variable conditions, while the second had previously been lost from the community. Additionally, many other varieties plucked from national genebanks found favour with specific farmers, often

because they outperformed 'improved' varieties in various ways. They are now being grown and distributed through the informal seed sector. The project has succeeded in placing much more diversity into the hands of farmers for them to adapt and use in their systems.

The farmers were surprisingly responsive to our requests. For example, farmers agreed to evaluate the same accession in two replicated fields, doubling the work. We scientists decided to acknowledge the farmers' participation in our research by naming them in the ensuing scientific publications. When we compared traits identified by farmers with DNA analysis of the durum wheat varieties, the farmer traits showed up in the DNA. This should make it easier for breeders to create new varieties that satisfy farmers' needs and can cope with climate change. We should recognize that farmers' varieties were replaced too fast and before we had adequate knowledge about their performance. It is time to bring them back when and where it is appropriate.

Carlo Fadda

2018 –today: Team Leader, Seeds for Needs

2010–today: Senior Scientist, Genetic Diversity

2008–2010: Global Project Manager, Pests and Diseases Project

Jesus started preaching to very few people but eventually he reached many many people. Similarly you started by giving very few seeds and now they are used by many.

Aba Adane Kassahun, a Monk farmer from Geregera

Seeds for Needs: India

Conventionally, plant breeders select new varieties based on their understanding of what farmers want or need. Using a crowdsourcing approach, in the Bioversity International-led 'Seeds for Needs' initiative in India, we turned this upside down, giving farmers samples of hundreds of varieties and working with them to select which ones suited their needs. The selected varieties went forward to trials, where each farmer received three random varieties and had to simply record their subjective best and worst on various traits. Software then combines the many individual results to present us with a result that accurately reflects the wisdom of the crowd and can rank the selected varieties from most to least preferred.

The primary aim of the 'Seeds for Needs' approach in India was to establish a network of farmer experimenters who were keen to broaden the genetic base of their farms with the ultimate goal of making their farming systems more resilient.

We knew that in order for farmers to meet the challenges of climate change and produce enough food to feed their families, they would need access to more drought-tolerant and heat-resistant seeds. The problem was how to find those seeds and get the farmers to use them. Smallholder and marginal farmers have very limited options. We believed that if they had more information about and access to a wide range of crops and varieties, they would make better choices according to their local conditions.

The research began in 2012 focusing mainly on wheat and rice, the two most important crops for food security in India. The idea was to stimulate farmers to experiment with different landraces and varieties, while we used geographical tools to make these efforts more targeted and efficient. Linking to local genebanks, we assembled a very broad selection of crop diversity, including traditional, modern and obsolete varieties. We started testing in 109 villages of two states (Bihar and Uttar Pradesh) with 50 farmers who participated in variety selection trials and 800 farmers for crowdsourcing.

By exposing farmers to more crops and varieties we increased their first-hand knowledge of the different traits and options available. That empowered them to make better choices. We also worked to strengthen their seed systems and seed-saving abilities, so that they would always have access to seeds that fit their changing needs.

By 2015, 15,000 farmers from more than 200 villages across 5 states (Bihar, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, and Orissa) were conducting crowdsourcing trials. As a result of the project, farmers adopted 39 varieties of rice and 43 varieties of wheat. Having access to this wide diversity should make their agricultural systems more resilient to climate variability. Rural communities are now better able to use adapted genetic materials through an improved local seed system network. Going forward, farmers are better able to identify suitable genetic material that will help them adapt to changing climates.

Prem Mathur

2016–today: Honorary Research Fellow

2015–2016: Regional Representative for Central and South Asia

2013–2015: Regional Director (interim) for Asia, the Pacific and Oceania

2008–2013: South Asia Coordinator

1995–2007: South Asia Associate Coordinator

Reflections from Leadership: Becoming Bioversity International

Emile Frison

Director General, International Plant Genetic Resources Institute/Bioversity International

2003–2013

The main achievement of my time as Director General was a real change in the organization's paradigm. First, as the International Board for Plant Genetic Resources (IBPGR) and then as the International Plant Genetic Resources Institute (IPGRI), the main function was conservation of agricultural biodiversity. The mantra was that plant genetic resources are essential to the future of agriculture, and that is why we must conserve them.

Our focus changed to the uses of biodiversity in the present, and their importance in, for example, nutrition, sustainable livelihoods and resilience to climate change. Once that had been demonstrated, investment in conservation would become easier. It was a shift away from conservation techniques to a broader view of the reasons for conservation.

The name change in 2006 to Bioversity International was part of that. I wanted to ensure that we did not consider plant genetic resources in isolation, but also the interactions with animal diversity, human cultural diversity and ecosystem diversity. That shift led to the change of name.

The shift we started is not a finished job. In fact, since the food price crises of the late 2000s, the focus of the mainstream has returned to economies of scale, the further industrialization of fewer crops and an emphasis on calories at the expense of nutrition.

We really need a change in paradigm, to break out of the narrow mindset of agriculture and development, and see that an agroecological approach, making full use of agricultural biodiversity, will make a greater contribution to sustainable food production and better nutrition than conventional approaches.

Tony Gregson

Board Chair, International Plant Genetic Resources Institute/Bioversity International

2005–2009

My introduction to the International Plant Genetic Resources Institute (IPGRI) as it was then called, was joining the Board in time for the election of a new Director General to succeed Geoff Hawtin. With a new Director General, we set about devising a new strategy and a new name: Bioversity International came into being.

The Bioversity Board Chair was then also a member of the Genetic Resources Policy Committee (GRPC), a greatly underestimated and underutilized CGIAR committee where I learnt so much about plant genetic resources and the International Treaty on Plant Genetic Resources for Food and Agriculture. The GRPC also reinforced the importance of biodiversity in people's lives.

Two other significant events come to mind. The formal merger of the International Network for the Improvement of Banana and Plantain (INIBAP) and IPGRI was finally completed after much discussion with the French authorities. Also, we had a very positive External Programme and Management Review. These are five-yearly reviews of oversight and accountability.

Finally, I must say that the real highlight of my time with Bioversity was interacting with all the wonderful, dedicated and inspirational people: Board colleagues, DG and all the staff members, dedicated to their work and the ideals of making the world a better place. .

Richard Markham

Director, International Network for the Improvement of Banana and Plantain

2003–2005

The pivotal moment of my tenure as Director of the International Network for the Improvement of Banana and Plantain (INIBAP) came in 2005 when INIBAP celebrated its 20th anniversary. A few months later, it merged with IPGRI and came to form the core of the Commodities for Livelihoods Programme of what would become Bioversity International.

It was a moment of mixed emotions for all of us on the INIBAP team. There was so much to celebrate. The Network's staff had grown, from five initially, to some forty people, deployed in four regional offices, as well as at the banana genebank hosted in KU Leuven and at the headquarters in Montpellier. Meanwhile, the scope of the research agenda had grown in complexity until it encompassed almost everything about bananas.

The core of our mission remained the same – the conservation and use of banana diversity. The collection of banana diversity in tissue culture had become something of a global model for vegetatively propagated crops – with a pace-setting management system, back-up collections cryopreserved in liquid nitrogen, and an impressive record of safe dissemination of germplasm to users around the world. Networking with leading researchers in genomics and bioinformatics had helped us to understand the diversity of banana genetic resources at a very fundamental level and to make that understanding available to users through an exemplary information system.

Our research, together with partners, had broadened to include: managing diversity – both within the crop and the cropping system – according to agroecological principles to make bananas more productive and sustainable; and research on post-harvest processing and market chains which had shown how banana products could contribute to diversifying livelihoods in low income countries.

These achievements were not lost with the disappearance of INIBAP. Rather, the banana team's experience of understanding, deploying and managing diversity for sustainably improved livelihoods placed their work at the heart of the new agenda of Bioversity International. Integrating the work on cocoa and coconuts with the well-established work on banana provided learnings to make rapid progress across these commodities too.

Despite the gains, however, it was hard not to feel some nostalgia for the loss of INIBAP's single-minded obsession: for saving 'the world's favourite fruit', the banana!

Staff

Meet our Staff: Rose Taremwa and Francis Njoroge

Rose Kyotungire Taremwa

Country Office Manager, Uganda

I appreciate the fact that if the generations before us hadn't conserved biodiversity, we wouldn't have access to medicinal tree species, seeds, soil organisms, insects and more, which we need to conserve for future generations. We especially need to protect forests and agriculturally valuable species whilst addressing global climate change challenges. With Bioversity International's work globally, I now more meaningfully appreciate the efforts to sustain the planet by attaining global food and nutrition security, the beauty of agricultural practices including new technologies, the natural environment of trees, flowers and water bodies, and I am motivated to maintain the natural world for our children and grandchildren to enjoy.

On the management side of things, I very much appreciate the workforce diversity of teams at Bioversity, which foster fresh ideas and perspectives, openness and an inclusive culture that provides staff with an opportunity to contribute to processes whilst creating a platform to learn from each other.

Francis Karanja Njoroge

2018–today: Administration and Finance Assistant, Kenya

I would like to place on record my enormous gratitude to the amazing team of scientists, data officers and field support staff who are committed and determined to be a force of good.

I am proud of what the organization has achieved over the years including assisting farmers with a whole basket of leafy vegetables which have more economic value as well as nutritional content, and of course the most amazing puffed cereals which have provided more ways of consuming cereals away from our tradition of porridge and ugali, and thus support livelihoods.

PRODUCE

Why farmers value agricultural biodiversity

The high-yielding varieties of the Green Revolution displaced landraces and farmer varieties on an enormous scale, especially in the areas most favoured for production of the staple food crops rice and wheat. It was the loss of genetic diversity that provided the impetus for the formation of the International Board for Plant Genetic Resources (IBPGR). However, while scientists worked to collect and store as much as they could of the agricultural biodiversity that remained in genebanks *ex situ*, away from farmers' fields, they continued to worry about diversity in the field. In farmers' fields, crops and varieties would continue to evolve as a result of natural and artificial selection. Both forms of diversity are needed to meet the unforeseen future demands of society.

Potentially valuable genetic resources were still being managed by farmers in remote areas when we began our research around 2000 as part of Bioversity International (as IPGRI – the International Plant Genetic Resources Institute)'s global on-farm (*in situ*) conservation project, under Devra Jarvis. We did not know how much genetic diversity there was, how farmers were managing it, and what motivated them to continue conserving that diversity in the face of economic and social change. That was what drove our research.

With a group of young researchers, mostly social scientists who themselves worked with an array of national scientific teams, we set out to discover and document who maintains diversity, where it is maintained and how much farmers value this diversity using quantitative methods. The group studied farmers in Ethiopia, Hungary, India, Mexico, Nepal, Peru, Uganda and Uzbekistan.

One surprise was that, even though resource-poor farmers grew landraces as a form of insurance, it was the relatively better-off farmers who tended to use more agricultural biodiversity on their farms. Often they were growing modern varieties too, but these existed alongside landraces, and each contributed to livelihoods in different ways. Modern varieties might provide cash, while traditional landraces were preferred for eating at home and might also have ritual uses.

Farmers derived two main benefits from conserving biodiversity on their farms. First, in challenging growing environments, diversity often reduced the variability of overall yield on the farm from season to season. More important, perhaps, it often mitigated the risk of total failure. A classic case of not putting all your eggs in one basket.

Information about diversity and strategies to minimize risk, along with the planting material needed to implement the strategies, circulated through village networks and marketplaces, and these were important aspects of social capital. As social scientists, the researchers were able to assess the age and gender dimensions of cultural knowledge about ancestral varieties, and stressed the need to involve youth and women, not just household heads, in on-farm conservation.

Documenting the multiple values that farmers ascribe to their traditional crops and varieties opened the way to a new phase of research – how to support these values through participatory research, capacity strengthening and favourable policies to create win-win results in which farmers are getting what they need from their farms, and by doing so are also conserving the world's genetic diversity.

Melinda Smale

Professor, Food Security Program, Department of Agricultural and Resource Economics, Michigan State University

2001–2005: Economist, joint appointment at IPGRI and the International Food Policy Research Institute

Increasing gender equality and social inclusion

Gender equality is a fundamental human right as well as a means to achieve multiple development outcomes and the more sustainable management of natural resources. Gender integration in research for development is essential for achieving scientific excellence, and has been shown to enhance the relevance and uptake of research findings.

Bioversity International has a long history of participatory research in which scientists and rural dwellers who manage their farms and local natural resources work together to identify and solve problems. Adding an explicit focus on gender to this body of work has allowed us to pursue, hand in hand, the goals of sustainable biodiversity management as well as gender equality and social inclusion. With a focus on the management of common property resources, such as forests, we have identified novel approaches to resource management. These build on the work of Bioversity pioneers such as Pablo Eyzaguirre, the late Bhuwon Sthapit, and colleagues, who identified steps to engage communities in a process of community-based biodiversity management.

Our research across global regions, from Burkina Faso and Cameroon, to India, Malaysia, Nepal, Vietnam and Central Asia, has shown the value of bringing women and men participants together in carefully managed 'contact zones' that foster social learning and that deliberately seek to level power relations among diverse participants. First, we engage in structured dialogues in gender-segregated groups. Then, the groups come together to discuss gendered perspectives, knowledge, and priorities. Through these dialogues, women's knowledge gains visibility, and participants develop a sense of group unity and a common vision for their shared resources. The overall process we have developed with participants enables collective action that underpins the sustainable management of biodiversity.

To these approaches, we have incorporated institutional innovations that challenge the norms that perpetuate social inequalities, so, as they are implemented, they help to create more equitable relationships in rural communities over time. For example, in

Burkina Faso, creating dialogues across gender, age, ethnic and livelihood groups which incorporate critical reflection about gender and generational roles in resource management processes has increased the active participation of women and young men in water user committees and their influence over decisions made, thereby ensuring that their interests are reflected in these decisions. These approaches have been adapted and adopted in other research and development projects that aim to achieve the twin goals of biodiversity conservation *and* gender equality and social inclusion.

Marlène Elias

2017–today: Gender Specialist, Rome, Italy

2016 – today: Coordinator of Gender Research in the CGIAR Research Program on Forests, Trees and Agroforestry

2013–2016: Gender Specialist, Serdang, Malaysia

"[Through the research,] women from different backgrounds came together, gained knowledge through group discussions and got inputs from the facilitators. We wanted to start processing and marketing forest products to earn some income. During the discussions, we gained skills in making a sweet kokum (Garcinia indica) concentrate. We also learned about packaging and labelling when we went to the market with the researchers to see how other similar products were being sold."

Nagaveni Hegde
Leader, Matrabhoomi Women's Group

Tropical fruit trees

Citrus fruit, longan, mango, mangosteen, papaya and rambutan originated in South and Southeast Asia, as a result of which the genetic diversity within each species is remarkable – India alone is home to over 1,000 varieties of mango. These fruit trees are important sources of nutrition, income and rural livelihoods. Farmers come up with innovative practices to conserve and use these valuable trees, but, despite their importance, prior to the project there were no coordinated efforts to use them for the benefit of the rural poor.

We wondered whether we could adapt the methods and practices that had worked effectively to conserve crop genetic diversity *in situ* to increase the support that tropical fruit tree species might offer to improve farmers' livelihoods.

The 'Tropical Fruit Trees' project, led by Bhuwon Sthapit, worked with farmers, local communities and national researchers in India, Indonesia, Malaysia and the Philippines on four commercially important and genetically diverse species: citrus, mangosteen, mango and rambutan. It built on research by Bioversity International (as IPGRI – the International Plant Genetic Resources Institute) from the mid-1990s, led by Bhag Mal, that worked with national partners in ten countries to collect and conserve *ex situ* disease-free genetic diversity of tropical fruit trees. That project had resulted in advanced techniques used in partners' national programmes and also identified elite fruit tree varieties with desirable attributes for growers and breeders.

The research studied the everyday practices that farmers and rural communities employ to conserve the diversity they use, in order to draw up a framework for on-farm conservation. 'Community biodiversity management' integrates farmer-innovated good practices with scientific analyses to come up with solutions that improve both conservation and rural livelihoods. The project trained several researchers in participatory methods, working with farmers and treating them as equal partners and stakeholders, crucial for community-based biodiversity conservation. For many researchers trained in the formal sector this required a transformational shift in mindset.

The project carried out on-farm diversity assessments and surveyed 36 communities in the four countries to identify farmers' best varieties with characteristics – colour, flavour or special culinary uses for example – that could add value and create market demand. The project established the potential to market nutrient-dense fruit collected from the wild as well as grown on farms, to benefit consumers and producers alike.

We interviewed many custodians of diversity and identified 95 varieties of mango, 32 citrus, 5 mangosteen and 2 rambutan across the four countries. We also collected 'elite' trees that were multiplied in 126 nurseries and made available to more than 77,000 farming households. A total of 99 farmer varieties were registered by the competent national authorities in the name of the local community or the custodian farmer. Registration means that communities can multiply and commercially market these fruit trees, a first step in recognizing the pre-eminent role that farmers play in the conservation and use of fruit tree diversity.

Ramanatha Rao

2007–2014: Honorary Research Fellow
1992–2007: Senior Scientist, Malaysia
1992–1997: Senior Scientist, Singapore
1989–1992: Genetic Diversity Officer, Rome, Italy

"Bioversity International provided a clear rationale, protocol and the impetus to conserve hundreds of wild aromatic pickle mango types of the Western Ghats and to strengthen the livelihoods of people associated with it, which I had always wanted to do."

Prof. R. Vasudeva, Professor (Forest Biology), University of Agricultural Sciences, Dharwad, India

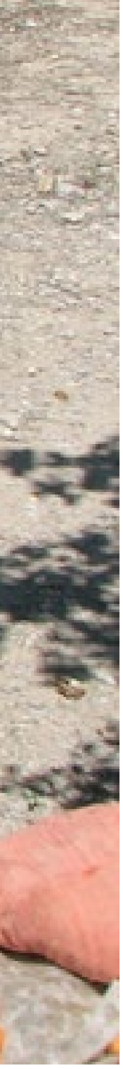
Central Asia fruit and nut trees

The collapse of the Soviet Union confronted the countries of Central Asia with several problems, not least a crisis of agricultural biodiversity. The transition to a market economy, along with changes in state support for agriculture, resulted in changes in land use, which triggered environmental degradation and agricultural biodiversity loss. Central Asia is a centre of origin and a centre of diversity for many fruit and nut species. The mountain slopes are home to selected varieties and wild relatives of almond, apple, apricot, cherry plum, currants, fig, grape, mulberries, peach, pistachio, pomegranate, pear, sea buckthorn, walnut and others.

In 2006, to safeguard these genetic resources and ensure that they could make a greater contribution to the livelihoods of smallholder farmers in the region, Bioversity International launched a project focusing on horticultural crops and wild fruit species in the area. The project worked along three tracks: improving the understanding of the problems, along with the capacity to solve them, at all levels; increasing the availability of planting material on a large scale; and working to implement a supportive policy environment.

A crucial element in the project's success was the way it was organized. There were local site committees, a national steering committee in each country and a regional steering committee. This gave stakeholders at all levels ownership of the project. Once priorities had been agreed in the regional steering committee, national governance took over. The regional committee allowed the partners to cooperate across all five countries without duplication, while each country was able to select its own priority species and targets.

At each target site, the project worked with local leaders among farmers and forest users to establish demonstration orchards and nurseries. These had two purposes. First, to inform others in the community of the ways they might use biodiversity on their own lands and in food production businesses. Secondly, to supply the planting material vital to



making more use of biodiversity.

Overall, nurseries inspired by the project have distributed hundreds of thousands of saplings across the region. Expanded plantings of fruit trees have improved livelihoods and food availability, and helped to restore degraded environments, because their root systems help to bind the soil and reduce erosion. The benefits have been particularly marked in unirrigated and drier areas, where fruit orchards have proved more resilient than other crops. The project also helped to raise awareness of the importance of the forests that harbour the wild relatives of the target species, and these are now better protected than they were.

In part, this is because farmers and scientists were able to influence policymakers. Kyrgyzstan and Uzbekistan introduced measures that protect the project's target species, while Tajikistan and Uzbekistan now favour farmers who plant orchards that include local or old varieties.

Perhaps the greatest impact of the project, however, is that the activities it catalyzed, such as the nurseries, are continuing to expand long after the end of funding support.

Muhabbat Turdieva

2006–today: Regional Project Coordinator

1999–2005: Forest Genetic Resources Scientist

Empowering farmers in the Sahel

Farmers in Sahelian West Africa (Burkina Faso, Mali and Niger) are poor in conventional terms, but possess two core assets: locally adapted seeds and the farmers' associated knowledge of plant diversity. Our project, 'Empowering Sahelian Farmers to leverage their crop diversity assets for enhanced livelihood strategies', built on that, operating on the basic assumption that the fight to overcome rural poverty should be led by the rural poor themselves. Smallholder farmers can be empowered to develop more effective livelihood strategies that lessen shocks, increase the value of their assets and create new opportunities for living healthy and productive lives in high-risk environments like the Sahel.

This approach entails a paradigm shift. Conventionally, development produces a package of technology and knowledge that is then transferred to farmers who are deemed to need the package. Instead, we adopted a farmer-focused strategy based on working with the farmers to identify and promote local crop and tree genetic resources. This paradigm shift is gaining ground in the Sahelian countries because support to local initiatives and innovations often proves a more sustainable way to tackle poverty.

To begin with, we wanted answers to some basic questions, like what makes farmers adopt practices they see other farmers using, and whether taking part in diversity fairs increases the diversity on their farms. It turned out that farmers trust each other far more than well-intentioned outsiders, and rapidly adopt new technologies such as new seed varieties, new crop management and new post-harvest technologies if they see other farmers using them successfully.

Working with local farmers, the project introduced a range of varieties adapted to pests and diseases and climate variability. We noted a reduction in crop failures, increased average crop yields, and less variability in yield from year to year — all of which improve food and livelihood security. Women farmers have created new enterprises to domesticate and sell seeds of novel vegetable crops such as *Senna tora* and *Ceratotheca* species.

The project produced social benefits too. Regular meetings of farmers at seed and crop diversity fairs strengthened interpersonal relations and cemented village cohesion. In Mali, local authorities made use of farmers gathering at diversity field forums to mediate in disputes.

It is hard to measure the impact of the project because its very strength — that farmers adopt from one another — means that innovations can spread far beyond the project's view. Nevertheless, at the end of a project meeting, one farmer said that in the past farmers had been too 'small' in front of researchers and had hidden their innovations. The project offered opportunities to share their knowledge and innovations. These farmers have become experts in their community and are now sought by other development projects to train their peers. The overall approach is now being scaled up and mainstreamed into national agricultural extension programmes in Sahelian West Africa.

Raymond Sognon Vodouhe

2001–2014: Regional Coordinator, West and Central Africa

1997–2000: West and Central Africa Plant Genetic Resources Network Coordinator

1978–1994: National Scientist

"Bioversity International has sensitized, motivated and strengthened our capacities for conservation and development of our genetic resources in a participative way. Our community genebank is a model in our region. We now have expertise that we share with other farmers."

Mr M. Matchirè Dembélé, Farmer and Chair of Diversity Field Forum in Bolimasso, Northern Mali
Mr Amadou Sidibé, National Coordinator of Plant Genetic Resource Management at IER, Mali

Ecological solutions give banana production a boost

Improving grower income and food security through crop density, frequency of replanting, associated crops and agronomic practices emerged as an important area of research as scientists from the International Network for the Improvement of Banana and Plantain (INIBAP) and the networks became more versed with smallholder production system diversity globally.

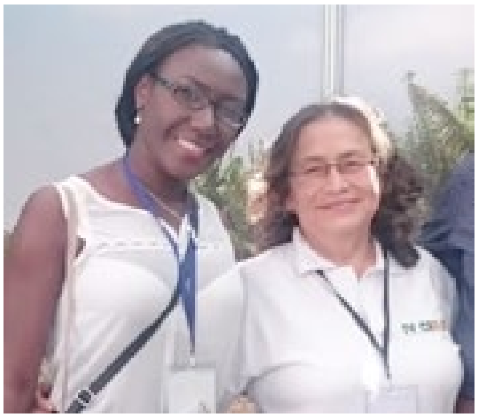
An early focus was the use of frequent replanting at high densities with high-quality, clean planting material (see photo). With national scientists from Latin America and Asia, my predecessors developed guidelines to improve yields for high price seasons and maintain banana production in areas with banana bunchy top disease. Recently we have shown that yields can be further improved by using planting material from superior and elite mother plants.

In 2003, Bioversity International (as INIBAP –the International Network for the Improvement of Banana and Plantain) introduced soil health to the banana world through a state of the art publication produced at a pioneering symposium. A follow-up field project identified key biological, physical and chemical indicators of soil health linked to banana productivity in commercial banana production in Latin America. Bioversity banana scientists have continued to explore strategies to manage Fusarium wilt disease using soil amendments and crop rotations to improve soil health in Australia, Brazil, Costa Rica, Indonesia and the Philippines. Protecting the soil and building soil biological activity reduces the spread of Fusarium wilt and increases the useful life of banana plantations. Screening the diversity of bacterial and fungal organisms in 25 banana types has generated a collection of over 500 organisms with potential to enhance plant growth and tolerance of different kinds of stress. Characterizations of the plant and soil microbiome in contrasting production systems by Bioversity and partners have pioneered this frontier in soil and plant health for banana.

Since 2008 intensification strategies – in which yields are increased through harnessing ecological processes – have provided the basis to improve diverse smallholder banana systems. Bananas cultivated in shade-grown coffee across the globe provide a regular supply of food and cash income. Groundbreaking work in Latin America addressed optimum light and nutrient management among overhead trees, bananas and coffee to get the most from the system. In Central Uganda, goats fed on leguminous shrubs planted along field borders and within the

field as much as tripled on-farm manure supply for bananas, leading to increased bunch size and shorter production cycles. Participating farmers observed that they had goats and shrubs prior to the project, but gained valuable insight about how to connect them through ecological analysis for greater productivity. Intercropping banana and beans and screening for shade- and drought-tolerant annual and cover crops are providing new options for ecologically intensifying production of banana types grown in East Africa. In the Dominican Republic, Ecuador and Peru, we showed that organic banana yields could be improved by up to 25% by strategically placing banana residues and fertilizers to create hot spots of root growth and biological activity.

The frontiers for the use of agrobiodiversity and ecological intensification for more productive, efficient, resilient and profitable banana production systems are still expanding with great promise for improved smallholder livelihoods.



Myriam Arias de López (right) Rosa Elena Corozo Ayovi (left), Instituto Nacional de Investigaciones Agropecuarias (INIAP) Ecuador

Charles Staver

2016–today: Honorary Research Fellow

2004–2016: Coordinator Sustainable Banana Production and Marketing

"Bioversity's scientific cooperation contributed to an understanding of ecosystem interactions in organic export banana and how growers can use this knowledge to orient practices which benefit soil health and limit harvest losses due to red rust, an important cosmetic damage to banana fruits."

Battling a devastating banana disease

Xanthomonas wilt is a devastating banana disease besetting banana farmers across the east and central African highlands. For many years only prevalent in Ethiopia, the disease jumped to central Uganda and eastern Democratic Republic of the Congo (DRC) about 20 years ago. Xanthomonas wilt is caused by a bacterium that is easily spread by contaminated tools and infected planting materials, as well as by flying insects, bats and birds, and small ruminants browsing on the banana plants. In some areas, the disease infected the majority of farms within a year of arrival. All bananas currently grown in affected zones are susceptible to the wilt. In the worst affected areas, the whole production of bananas can be wiped out.

Initially the control strategy focused on early male bud removal to prevent spread by insects, and persuading farmers to sterilize their tools when moving from one plant to another. Although time-consuming and tedious, farmers were encouraged to uproot the entire mat, from which several banana stems may emerge, at the first sign of the disease. Research by scientists at Bioversity International and the International Institute of Tropical Agriculture revealed that the bacteria do not easily move from one stem to another through the tissues that connect them in a mat. In fact less than a quarter of the stems attached to a visibly infected stem develop symptoms of Xanthomonas wilt. These results prompted a new control technology; remove only visibly diseased stems, by cutting them off at soil level.

Researchers tested this single diseased stem removal (SDSR) approach in the village of Katana centre, in South Kivu, eastern DRC, in banana fields where more than 80% of the stems were infected. Incidence of the disease plunged to below 2% within three months and to below 0.5% within ten months.

SDSR has the potential to bring the disease under control within a year while saving labour and money. More importantly, it increases the options available to farmers, who can choose management approaches depending on conditions on the farm, farming system, household details and livelihood strategy. SDSR works well for smallholder subsistence farmers who often have very large mats of more than five stems in their fields. Market-oriented farmers, who often prefer mats with only three to four stems and have access to labour, might choose complete mat uprooting.

In order to improve banana disease recognition, speed up surveillance and enhance the application of control strategies, researchers are evaluating the use of drones and machine learning to identify diseased stems. Smartphone apps will help to quickly detect the disease and spread information not only about the disease, but also about options to control it. The current main disease front is slowly moving from the eastern DR Congolese highlands into the adjacent Congo basin. Drone-based surveillance and smartphone-based apps will come in handy to raise awareness and curb disease spread.

Guy Blomme

2008–today: Scientist Integrated Banana and Enset Systems

"The SDSR method to control banana Xanthomonas wilt helped my family to rehabilitate our banana plantations which were destroyed by the disease. I wrote on one of the living room walls of my house the date I harvested the first bunch after starting to apply the SDSR method, because I will never forget the importance of SDSR and Bioversity in helping me to rebuild my banana beer business."

M'Cihimbi Helene Namazuba, farmer

Diversity bugs pests

Worldwide, farmers lose more than 25% of their annual crop harvest to pests and diseases. Low-income countries experience the greatest devastation. Breeders are in a constant race to develop new varieties with resistance to new forms of pests and diseases as they evolve.

Integrated Pest Management (IPM) strategies focus primarily on using agronomic management techniques to reduce pesticide use, modifying the environment around predominantly modern cultivars, using biotic control. These methods, however, tend to exclude the potential for poor farmers of using within-crop diversity as a means to regulate pest and diseases. In addition, the majority of IPM strategies concentrate on reducing current loss to pest and diseases. They are not yet oriented to reducing the risk of future crop loss (posed by reducing genetic vulnerability within farmers' fields) to new mutations of the pathogen population within the farmers' field or migrations of new pathogens.

The pest and disease work was built on Bioversity International's on-farm conservation research programme, with a large interdisciplinary team of local to national organizations in China, Ecuador, Morocco and Uganda. Together, the team developed and implemented common protocols for agreed host–pest pathogen systems for rice, maize, common and faba beans, banana and plantain, and durum wheat, assessing and using high levels of diversity of traditional and commercial varieties to reduce pests and diseases. The national researchers trained site-level personnel in common participatory approaches and technical assessments of genetic diversity, pathogens and pests, and supported the implementation of on-farm experimental trials. Ministries of Agriculture, national agricultural research systems and local governments provided policy support and allocation of staff and students to work with farmer communities. Researchers and farmers tested the use of this intraspecific diversity linked to good agronomic management practices on farm, on station and the materials evaluated in laboratories. One result of the research was strengthened access to high-quality diverse planting materials and improved capacity, particularly of woman farmers to use crop genetic diversity to reduce crop loss. Adopting variety-rich approaches increased farmers' crop yields on farm.

We worked with local partners to make more diversity available through

diversity fairs, demonstration trials, community seedbanks, diversity kits, participatory variety selection and community meetings. In the context of the project, students (50% of which were women) achieved 20 bachelor, 29 master and 11 doctorate degrees in on-farm management, mixture trials and diversity analyses. Over 30,000 farmers (around 45% women) have been trained to produce and store clean seeds. In China the villagers of Bada are now promoting the use of intraspecific crop diversity and sharing their experiences with other farmers at the local market. In Ecuador, farmers are requesting planting materials of traditional banana varieties that they have seen in on-farm trials to be resistant to black Sigatoka.

With new partners joining the original project over the last few years, the target crops have increased to include high-elevation rice, common bean and buckwheat in Nepal, barley and durum wheat in Ethiopia, temperate fruit tree diversity in Uzbekistan, and sorghum and millet diversity in Mali.

Devra Jarvis

2012–Present: Principal Scientist, Genetic Diversity Productivity and Resilience

2000–2011: Senior Scientist, Agricultural Biodiversity and Ecosystems

1996–1999: Scientist, *In Situ* Conservation

"The local varieties display a good quality in terms of taste, good productivity and adaptation to climate changes. They resist drought and disease incidences. In addition they produce large quantities of straw that are used in animal feeding"

N. Ourdghiri, farmer, Morocco

Biodiversity, a means or an end?

Agricultural research for development is challenged with how to feed a continuously and rapidly growing global population expected to reach 10 billion by 2050. In the face of this acute need, much research for development has focused on ensuring that food production, notably calorie production, keeps pace with population demand. This strategy has been successful, and food insecurity has significantly decreased globally. However, this has come a significant cost to the environment and pits biodiversity conservation and food security as opposite if not incompatible goals. In the face of rational fears about hunger, biodiversity most often loses. Today's food systems are wreaking havoc on both wild and agricultural diversity.

In the 1990s, ecosystem services emerged as a concept that emphasizes biodiversity's contribution to people – not replacing the approach of biodiversity as a conservation goal, but complementing it by recognizing biodiversity as also a means to the end of human well-being.

Agroecology teams at Bioversity International have, since 2010, been focused on functional ecology to understand how these services work in nature, increasing their use and efficiency in the field, and testing what species traits or types of biodiversity are most important for securing services. The struggle by ecologists to synthesize countless species traits and understand their contribution to farm-scale services was rather infuriating – until we realized that the nutrition community had done much of the work for us, and were already doing trait-based assessments of foods in diets. Measures of functional dietary diversity were born, which supported the role of dietary diversity in improving human health, and flagged the need for more nutrition-based outcomes to guide agriculture.

At landscape scales, Bioversity research teams learned from nutrition and increasingly sought stakeholders in the field to first understand what benefits were being sought, then working backwards to understand how arranging vegetation diversity in agricultural landscapes contributed to reducing crop losses from pests and diseases, improving water quality and energy generation.

The team increasingly worked across scales, from farms to landscapes – and in collaboration with nutrition teams on 'nutrition-sensitive landscapes' with communities globally to understand how integrating multiple stakeholder goals at landscape scales might produce agricultural landscapes that benefited both conservation and development outcomes.

In 2019, in collaboration with EAT, we have published what might be the first science-based targets for food complete with dietary guidelines for healthy foods, and environmental guidelines for sustainable food systems. These science targets recognize that conservation and production do not need to be at odds with each other, and that biodiversity is both a rational means and an end. Notably, the report, *Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems*, emphasizes that globally, fruit, vegetable and nut consumption, and thus production, need to nearly double by 2050 to provide healthy diets for all. The dietary shifts needed to secure human health, accompanied by productivity increases required place agricultural diversity and dietary diversity front and centre in the global development challenges of the coming decades.

Fabrice DeClerck

2016–today: Senior Scientist, Bioversity International/Science Director, EAT

2012–2015: Programme Leader and Scientist

Fabrice with team. From left to right: Sarah Jones, Fabrice, Natalia Estrada Carmona, Roseline Remans

Home gardens

Genebanks and *in situ* conservation projects provide much information on the rich agricultural biodiversity in farmers' fields, its richness, distribution and threats. However, in the mid-1990s, we noticed some gaps in our agricultural biodiversity knowledge.

First, the central role of women in the management of genetic resources was often ignored. Second, the small niches and micro-environments where distinctive agricultural biodiversity is developed, exchanged and conserved were often overlooked. The places are home gardens, usually tended by women and children, where a mix of trees, shrubs, flowers, herbs, vines and roots produce the kinds of vegetables, herbs, starchy crops and fruits that are valued in the local food culture and health traditions, but often poorly known and scarcely documented. Traditional crop varieties being displaced from markets and fields were being safeguarded in home gardens for those unique taste and health traits that were fancied and valued by women and their families. Global research has now shown that these gardens are major sources of fruits and vegetables and herbal medicine for a majority of rural communities.

Culturally, gardens are important spaces. Often the women in charge of the home gardens were grandmothers, looking after children, while younger men and women worked in the fields or off farm. Home gardens are ecologically complex niches where people create and manage a multi-story plant community that can be wild or cultivated. They often look wild, probably because they were deliberately mimicking a natural environment. For many creatures, such as migratory birds, home gardens are a more important habitat than threatened and diminishing forests and fields. Home gardens thus create a link between wildlife conservation and plant genetic resource conservation. This enabled Bioversity International to forge and strengthen partnerships with the global environmental conservation community.

Bioversity's 10-year global home garden study, including Cuba, Ethiopia, Ghana,

Guatemala, Nepal, Senegal, Venezuela and Vietnam, developed methods to survey such diverse habitats and then expanded to other countries in areas of high and low natural biodiversity. In Vietnam, home gardens are often experimental areas to try out new crops such as chayote (*Sechium edule*), which had more diversity there than in its home in Central America. By contrast, in areas of limited biodiversity, such as in dry areas of Ghana, home gardens preserved culturally important indigenous crops, like millet, which was being replaced in farmers' fields by maize and sorghum.

Home gardens allow varieties to continue to adapt to changing environments: comparing beans grown in home gardens in Cuba with nominally the same varieties stored *ex situ* showed them to be quite different.

Home gardens are now a nexus for work on biodiversity conservation, household food and nutrition security, family and child health, as well as the maintenance of healthy ecosystems. While we focused on rural areas, the lessons are proving useful in promoting the use of biodiversity in urban farming as well. This work ultimately stimulated Bioversity International's interest in taking a more direct approach to diversity for nutrition.

Pablo Eyzaguirre

2015–today: Honorary Research Fellow

1995–2014: Senior Scientist, Anthropology, Ethnobotany and Socioeconomics

Community forestry: a win-win solution

Tree diversity can be conserved only in populations of living trees, so Bioversity International's research on conserving tree genetic resources focuses on sustaining the forests where the trees grow. Most of these forests are dedicated to timber production; almost half are managed by communities and the rest are largely under state control, with concessions granted to the timber industry.

In Guatemala, we focused on 800,000ha of tropical forest in the Maya Biosphere Reserve, where community associations have the right to harvest timber. We wanted to know whether logging affects the genetic diversity of mahogany (*Swietenia macrophylla*), the most valuable timber species, and to measure economic returns of timber harvesting for the communities. In other words, is community forestry a win-win solution for both conservation and rural development?

To answer the first question, we collected leaves and seeds from mahogany trees in logged and unlogged forests to analyze their genetic diversity directly. We also sowed samples of the seeds in community nurseries and measured germination percentages, which indicate levels of genetic diversity. Economic answers were obtained through interviews of participants in three forestry associations.

Results showed that harvesting mahogany timber had not diminished the genetic diversity of mahogany and that communities earned enough from forestry to raise households above the poverty line; forestry is a win-win. Non-governmental organizations are now using this information to argue that community concessions should be renewed after their first 25 years: the concessions have effectively safeguarded the forest while improving the lives of the residents there. Community women who had watered the seeds and counted the seedlings that germinated became enthusiastic advocates of conservation and restoration of these forests.

Another recent project focused on the tropical forests of Cameroon, Gabon and the Democratic Republic of Congo. There, the state owns the forest and grants timber-harvesting rights to export industries, but the forests are also home to millions of villagers who depend on forest resources.

Working with local partners, we focused on fruits and edible caterpillars from five valuable timber species. We asked whether villagers collect fruits and caterpillars from within the timber concession, how many trees of each species are found within 10km of the villages and how many are found in the timber concession, and whether logging is depleting the availability of these foods. Our analyses revealed that villagers collected mostly within 5km of their villages, only sometimes venturing onto the timber concession. The density of

trees around villages and on concessions varied by species and also by size class. Concessionaires left standing many trees of harvestable size, which continued to provide fruits or caterpillars.

These insights provide the foundation for management plans to ensure that villagers have access to these foods without impeding timber concessionaires from harvesting trees. In addition, more than a dozen students from the three countries obtained graduate degrees and co-authored their first articles through the project.

Laura K. Snook

2018–today: Honorary Research Fellow

2015–2018: Research Team Leader, Forest Management and Restoration

2012–2015: Programme Leader, Forest Genetic Resources Conservation and Sustainable Use

2005–2012: Programme Director, Understanding and Managing Biodiversity

"At ACOFOP we greatly appreciate how research done in collaboration with Bioversity International has helped us to document the sustainability of our forest management activities, and to better understand the economic benefits that this brings to communities, as well as the risks we have to face to maintain the benefits of community forest management for communities. The research allows us to demonstrate to government agencies that sustainable forest management carried out in the multiple use zone of the Maya Biosphere Reserve guarantees the resource long term. We hope this will convince them to extend the community concession contracts."

Julio Madrid of ACOFOP – Asociación de Comunidades Forestales del Peten

Regreening degraded landscapes

"That's the topic that has the least to do with genetic diversity".

This was the general belief when, in 2010, the Food and Agriculture Organization of the UN (FAO) commissioned Bioversity International's Forest Genetic Resources team to write a thematic study about the use of native tree species in forest and landscape restoration.

The restoration study was for the first report on the *State of the World's Forest Genetic Resources*, covering topics from the effects of forest management on genetic diversity and the use of tree genetic resources for livelihood improvement to adaptation to climate change. FAO and national partners suggested that the restoration study focus on native species in restoration and ways to increase those as a means of biodiversity conservation.

Diving into the literature, two things became clear. First, species diversity is important, but genetic diversity within species is more important in restoration than initially assumed. Genetic diversity is vital for the growth and survival of seedlings, productivity, resistance to pests and diseases and adaptiveness to environmental change. It relies on seed collectors collecting diverse seed. Second, the perception that genetic diversity was irrelevant to restoration was understandable: only a handful of studies had been published about the genetic diversity of restored forests. Three-quarters of these indicated that poor seed collection practices led to significantly lower germination, higher mortality or slower growth in restored than natural forest. In the context of a required annual investment of US$34 billion in forest restoration, these high failure rates were startling.

We surveyed forest and landscape restoration practitioners worldwide to find out what was behind these findings. The results showed that sourcing sufficiently diverse tree seed is a widespread problem in restoration. Four-fifths of projects obtained seed from the nearest remaining natural forests, typically with little attention to habitat degradation or fragmentation, which reduce the viability of seed. Using a narrow genetic diversity of seed was a problem especially in large projects and those aimed at mitigation of climate change. Four out of five respondents had trouble finding seed for their projects in markets. In almost half of the projects, these problems had resulted in higher costs, delays in project implementation, having to restore the same site again, or all of the above.

The Secretariat of the Convention on Biological Diversity invited us to share the thematic study findings through regional capacity strengthening workshops in Asia, Europe and Latin America. And in 2014, the 12th Conference of the Parties to the Convention adopted a resolution calling

for all parties to consider genetic diversity in restoration.

Bioversity now runs a whole research programme on tree seed for restoring degraded landscapes. It explores quality, availability of and access to tree seed and the potential for large-scale restoration opportunities to generate jobs and income for local communities as seed collectors or nursery entrepreneurs.

This work is sorely needed, as world leaders have committed to restoring 350 million hectares of degraded forests and landscapes (greater than the area of India) by 2030. That means sourcing genetically diverse seed for 100 billion new seedlings!

Riina Jalonen

2017–today: Scientist

2013–2017: Associate Scientist

2013–2009: Associate Expert

Evert Thomas

2007–today: Scientist, Latin American Forest Genetic Resources

"The results achieved have provided great progress for the communities´ livelihoods and the increase of environmental goods and services available to them. Bioversity provided us with tools that [guide] restoration decisions for tropical dry forest in Colombia (restoration and propagation protocols, interactive map, among others). Interaction with Bioversity also allowed us to better understand survival rates and installation costs of different restoration interventions in tropical dry forest, an area where almost no knowledge existed"

Luis Gonzalo, Forestpa

Resilience through landscape diversity

What socioecological production system or combination of systems offers the best options for producing enough food while conserving biodiversity and the ecosystem functions associated with it?

A landscape approach helps us understand the ecological interconnectedness between natural and cultivated systems, and so to answer the question. An agroecosystem with a mosaic of different sustainable land uses and crops, including crop varieties, is more resilient to climate change. Greater variety in the landscape supports a greater diversity of species, and a greater diversity of species means that there is increased likelihood that species will be able to provide certain functions and to adapt to changing conditions. Diversity in an agricultural landscape allows portions of high-diversity native vegetation to persist along with biodiversity-friendly agroecosystems to form an integrated landscape that facilitates the presence and movement of wild species. Resilience depends on the environmental quality of the landscape and the capacity of local communities to embrace innovation and yet conserve traditional knowledge. Communities also need to have equitable rights over natural resources and to collaborate with other communities and stakeholders on common resource management. This allows them to maintain their livelihoods and well-being from their agricultural activities.

To understand the resilience of agricultural or production systems within a landscape framework, we developed, in collaboration with the United Nations University Institute for the Advanced Studies of Sustainability, Community Development and Knowledge Management for the Satoyama Initiative and the Institute for Global Environmental Strategies, a set of indicators that would help communities assess the elements of the system that contribute to their resilience. We tested the indicators in 11 different countries across different agroecological systems, from the highland potato and quinoa plots of Bolivia and the tropical agroforestry systems of Cuba to the rice paddies of China and the Philippines and the coastal landscapes of Fijian islands.

This research adds evidence to the debate on land sparing *vs.* land sharing, demonstrating that small-scale, sustainable agriculture is not only able to produce enough good-quality food but is also the best possible option for biodiversity conservation. The research

also highlights the importance of consultation and involvement of local stakeholders and communities in any decisions that influence landscape management. It further shows that to understand the complexity of landscape dynamics we need an integrated multidisciplinary approach.

Local farmers' communities have had the chance to voice their aspirations for the future, to develop landscape-strengthening strategies according to their worldview and values, and to evaluate the quality of their farms as contributors to biodiversity conservation and to the delivery of ecosystem services. This exercise has also helped them to understand the possible consequences of their actions on natural environments and thus to adjust some of their management practices. In Cuba, farmers have also taken part in consultations with the managers of protected areas and have seen their role as custodians of agrobiodiversity and local knowledge recognized at the highest levels.

Nadia Bergamini

2012–today: Programme Specialist, Agroecology and Resilience

2009–2011: Programme Assistant

"The benefits I received from this project are in terms of increased knowledge on farming techniques, exchange of seeds with the west part of the country and the possibility to travel abroad and meet farmers from other countries."

Margot, farmer from Municipio of Manuel Tames, Guantanamo

Traditional crops on the rise in the mountains of Nepal

Smallholder farmers in the mountains of Nepal depend on traditional crops for their food and nutrition security. These crops include amaranth, buckwheat, barley, beans, different species of millet, cold-tolerant rice and other minor crops. They are nutrient dense and climate resilient, with unique traits of cold, drought and disease tolerance, well adapted to harsh and risk-prone mountain environments under changing climates. For generations marginalized mountain communities have relied on these crops for their food and nutrition security. However, their genetic diversity is threatened by the commercialization of agriculture, changes in food culture, outmigration and climate change. Moreover, these crops are undervalued, so research and development systems neglect them.

In order to better understand and promote the diversity of these traditional mountain crops, in 2014 Bioversity International and its partners launched a project on 'Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas'. The project focuses on eight traditional mountain crops in four Himalayan mountain districts of Humla, Jumla, Lamjung and Dolakha spread across the whole country.

The project has developed strong partnerships with national institutions and community-based organizations. We have been using participatory methods with local farmers and their communities, to evaluate, promote, integrate and use technologies and good practices for the traditional mountain crops.

Initially we deployed a broad range of 300 traditional crop varieties, sourced from national genebanks, other research centres and project sites, to the communities, who between them identified 60 superior varieties for further evaluation and promotional activities. Activities include trying the farmers' preferred varieties in their fields and using participatory methods to improve them. We also worked with communities to establish community seedbanks and to set up diversity field schools and biodiversity fairs that link to food fairs, value chains and market development. Half a dozen of the superior farmer-selected varieties are now in the process of national listing and official registration. This will allow farmers to produce and distribute quality seed as an income-generating activity, and will enhance access and benefit sharing for the communities.

One factor constraining use of these traditional crops and their products is that some are difficult to prepare. The project is piloting processing machines

Credit: IWMI/Neil Palmer

modified for dehusking minor millets, to reduce the drudgery of women's work. These machines also reduce the cost of production and so will make these nutritious foods more widely available.

The improved varieties, good practices (e.g. community seedbanks, diversity field schools, biodiversity fairs linking food fairs) and processing technologies developed in the project are reaching around 20,000 small farmers in suitable mountain agroecosystems. More than 60% of the people benefiting from the project are women. We are now focusing on boosting the integration of these new technologies for traditional mountain crops by creating a policy environment that will enable and support registration, production, processing and promotion of farmer-improved varieties. These efforts are forging links among local and national government, the private sector and R&D agencies.

Devendra Gauchan

2014–today: National Project Manager

"The project provided technical support and made us aware of the value of local crops. We received support to establish a community seedbank in the village. The project also made available electric machines for processing finger millet and proso millet, which have given great relief to women like us by reducing the difficult pain of manual threshing."

Ms Depsara Upadhaya, farmer from Chhipra, Humla

Reflections from Leadership: The last decade

Paul Zuckerman

Board Chair

2010–2013

I joined Bioversity International (as IPGRI – the International Plant Genetic Resources Institute)'s Board in 2005, after a career as an agricultural economist at the World Bank and a second career in finance in the City of London. My first contact had been with IPGRI in 2003 when CGIAR invited me to be part of an External Programme and Management Review panel looking at finance, governance and social sciences. One of the panel's recommendations was that the organization strengthen the role of economics in its research and on its Board, so I was delighted when, a couple of years later, Bioversity asked me to join the Board.

Much of my work as Board Chair focused on securing the future of Bioversity by broadening its support base. I pushed for directing fundraising at non-traditional donors. Among the changes I introduced were reducing the size of the Board and changing its composition to include people who were well placed to advocate for greater support. That meant reducing Board meetings to a day or a day and a half in Rome, because these were busy people who could not spare more time. One benefit of that was to free time for Board visits to Bioversity projects in the field from the somewhat inflexible timing of Board meetings, so we could go at the right time of year, when there would be something valuable to see in the field.

Board visits took place every 18 months or so and it was on one of these, to look at the work on African leafy vegetables in Kenya, that I really came to appreciate the difference Bioversity was making. I already had a first-hand appreciation of the difficulties that face small-scale farmers every day, having conducted my doctoral research in southwest Nigeria with the International Institute of Tropical Agriculture. My main interest was on how and why small-scale farmers make their decisions, within the complex systems they operate in.

In Kenya, I saw that we were playing a role that nobody else was playing. Bioversity brought together agronomic advice for farmers, information on the nutritional benefits of traditional foods and training in sales and marketing, working with appropriate partners in each sector to promote the many values of African leafy vegetables. Small-scale farming is a precarious business and farmers, many of them women these days, have to take many decisions to minimize risk. Biodiversity is an essential weapon in their armoury. I am proud to have helped Bioversity help those small-scale farmers.

Cristián Samper

Board Chair

2014–2016

I had the privilege of serving on the Bioversity International Board for eight years, including three as Chair. It was a time of change in CGIAR, as the new governance, framework strategy and cross-cutting CGIAR Research Programs were established. This created a challenge and an opportunity for Bioversity, as core funding was reduced and we had to develop a new strategy and make changes to our operations. This enabled us to build stronger partnerships with other CGIAR Research Centres and started a process that resulted in the Alliance with the International Center for Tropical Agriculture (CIAT).

Some of the best memories of my tenure were the visits to see our projects in the field. We visited communities in Ecuador and learned about the different varieties of beans they used, and how they enhanced resilience to changes in climate and pests. We visited the mountains of Uzbekistan to see the conservation of wild varieties of apples and other fruits. We visited the banana germplasm banks in Leuven and went to the field in Uganda to see how new varieties resistant to disease saved the lives of farmers. In Ethiopia we visited the 'Seeds for Needs' project, which builds community seedbanks and works with farmers to test varieties across environmental gradients.

The quality and impact of our work depends on our people and partners. I would like to thank our staff for their dedication and commitment to our mission and strategy. I would also like to thank our Board members for their time, advice and support. Our donors provide critical support to sustain our work over the years, and our partners are critical to leverage these resources and have great impact.

As we celebrate 45 years of work we can be proud of the contributions we have made to CGIAR and the world, but we must continue to evolve our strategy to tackle the biggest challenges of our time. Our mission is more relevant than ever before, as we work to conserve agricultural biodiversity and use it to improve the lives of people across the world in the face of challenges like climate change .

M. Ann Tutwiler

Director General

2013–2019

I joined Bioversity International as Director General in 2013 and what struck me most during my six-year tenure was how the recognition of agricultural biodiversity as a solution for sustainable food systems became mainstream during this time. One of the reasons for this is the mounting scientific evidence of just how agrobiodiversity can contribute to food systems that nourish people and nurture the environment, enhancing environmental, economic and social health. In 2017 we published our flagship book *Mainstreaming Agrobiodiversity in Sustainable Food Systems: Scientific Foundations for an Agrobiodiversity Index*, which gathered all this evidence together and really helped put the topic and Bioversity International on the international stage.

Perhaps the most significant driver of this sea-change occurred two years into my tenure with the adoption of the Sustainable Development Goals. The 17 Goals connected previously standalone challenges – for example, zero hunger, strengthening climate resilience and halting biodiversity loss – to global food and agricultural systems. By making these connections across different global challenges, the goals made it clear that our food systems are a major part of the problem and had to be a major part of the solution.

The first time I witnessed the high-level dialogue on mainstreaming biodiversity for sustainable food systems turning into action was at the Convention on Biological Diversity's 13th Conference of the Parties in Mexico in 2016. Bioversity International was there to present the Agrobiodiversity Index, a tool for countries, companies and projects to track and measure agrobiodiversity in diets, production systems and genetic resources. The room was packed. Policymakers, private sector representatives and many others had come along to learn more and find out how this new tool could help them to mainstream agricultural biodiversity into their food and agricultural systems.

Yet, my time as Director General also had its difficult moments. The upturn in interest in our mission coincided with a drop in funding to the CGIAR system, which deeply affected Bioversity International, leading to three separate rounds of painful layoffs and belt-tightening. 2015 and 2016 will stand as two of the most difficult years Bioversity International ever faced.

In 2019, the future is bright. We have signed a Memorandum of Understanding with the International Center for Tropical Agriculture (CIAT) securing the foundations for an Alliance to deliver greater impact at scale. Also, in my last week as Director General, I attended the launch of '50 Future Foods' – an initiative by Unilever-Knorr and WWF-UK to introduce 50 nutritious, resilient and forgotten foods into their product range. It is initiatives like these that really will turn theory into practice and lead to a sustainable food future for all of us.

Staff

Meet our Staff: Mateo Garzon and Nina Jakobi

Mateo Garzon

2018: The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) Intern assigned to the Lima Office in Peru

What I appreciate about Bioversity International's work today is that it has managed to create a worldwide platform of very talented scientists that provides scientific evidence for identifying the best ways of nourishing people while caring for the planet. I find remarkable its commitment to use such scientific knowledge in favour of the development of the people; partnering with key actors in developing countries for instance, is a way to take research into action, to have a real impact on people's livelihoods and the sustainability of the planet.

Nina Jakobi

2018: Programme Management Assistant, Leuven, Belgium

What I appreciate about Bioversity International is not only its mission to improve the diets of those who need it most – but also the working environment that is characterized by a very humane approach and mutual respect among colleagues that motivate and support each other in striving for excellence in continuing the challenging work towards a better tomorrow.

CONSUME

Food biodiversity for better health and nutrition

Eating a range of foods from nutrition-rich food groups – fruits, vegetables, pulses, nuts, seeds and whole grains – is a universal recommendation to help consumers meet nutrient requirements and maintain good health. Food biodiversity can be used to improve diversity and enrich diets of all ages.

Bioversity International's vision is to bring back local food biodiversity to improve nutrition and livelihoods. Updating the knowledge on the nutritional value of food biodiversity is a core scientific component of our work. With the CGIAR Research Program on Agriculture for Nutrition and Health, we provide metrics and methods to build healthy diets through understanding food systems. We advocate using basic metrics, such as diet diversity of women and children, to benchmark progress, and seek new metrics such as dietary species richness to measure the food biodiversity in our food systems.

At a local level, we engage with communities to understand locally available food biodiversity and increase its use to improve diet quality and income. We use community-based approaches, such as seasonal food availability calendars, to document locally available foods by season and then work with communities to integrate these foods better into their food systems and diets. For example, in Benin we added local, nutrient-dense foods to the foods traditionally given to children, to increase their vitamin and mineral intake. In Mali, a seasonal food availability calendar indicates the fruits and vegetables available month by month, and nutrition education helps motivate greater uptake. Together with local communities, we research solutions to how these foods can be taken up more widely. For example, we work with communities to integrate local and traditional foods into school meal programmes to improve producer income, increase the diet quality of school meals and reintroduce these traditional foods to young people. With nutrition clubs, we organize food fairs and cooking

demonstrations that highlight culinary uses of local food biodiversity.

The importance of food biodiversity is gaining international recognition. In Brazil, legislation under the Food Acquisition Programme pays a premium of 30% for agroecological and organic products and the National School Feeding Programme provides incentives for linking local farmers and agricultural biodiversity. Since 2009, by law, 30% of food procured for school feeding under this programme must be sourced from local family famers. In Asia and the Pacific, eight countries in the Future Smart Food Initiative have identified 39 neglected and underutilized species as priority crops for their food systems.

I am privileged to work with partners in communities throughout Africa, Asia, the Pacific and Latin America to improve the supply and demand for healthy food options using food biodiversity. Some of the brightest moments are seeing communities, such as this one in Zambia, celebrate the bounty of local foods and pass this knowledge on to their children. We have seen rapid improvements in diet diversity when agriculture and business skills are combined with nutrition education at local level. We also witness advocacy at international level for food systems to transform for better health of people and planet.

Gina Kennedy

2013–today: Senior Scientist, Nutrition and Healthy Diets

African leafy vegetables

In Kenya, in the mid-1990s, despite 210 documented traditional leafy vegetables, only three dominated markets and local foods: cabbage, kale and Swiss chard. Although traditional leafy vegetables are important in relishes or as side dishes in local cuisines in sub-Saharan Africa, governments and development agencies showed little interest in them. As African nations sought to modernize, these foods had become associated with backwardness and poverty, and their use was dwindling. And yet, African leafy vegetables are a valuable source of vitamin A and other micronutrients, not to mention being delicious and a source of income.

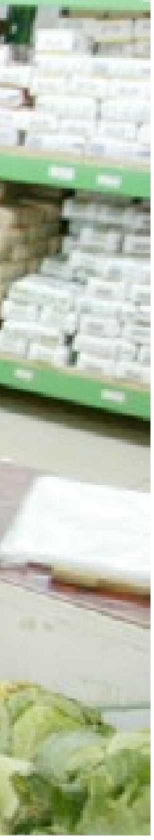
In 1995, I was in a team that organized the first international workshop on the genetic resources of traditional vegetables in Africa and laid the groundwork for a regional strategy to conserve and promote them. For the next decade, we carried out a programme in twelve sub-Saharan countries to reverse the decline and improve their contribution to nutrition and health.

The success of the exploratory phase in the late 1990s led to an expanded programme in 2001, partnering with the World Vegetable Centre and 38 other institutions in the region. We wanted to get more people eating more of these nutritious leafy vegetables, creating demand at the same time as enabling farmers and the value chain to meet that demand.

Over the next six years, we gathered germplasm of 24 priority species and improved it using facilities at the World Vegetable Centre. We multiplied and distributed these improved seeds. Farmers on the outskirts of Nairobi received agronomic support, training in processing and links to formal markets, initially the Uchumi supermarket chain. We promoted the vegetables through field days, cooking demonstrations, media programmes and street campaigns.

By 2003, a wind of change was noticeable. People were consuming the vegetables more, creating unprecedented demand; most supermarkets were now selling them. Attitudes had changed, from a source of stigma to a matter of pride. The traditional vegetables were now interesting to development workers and researchers. It was a good time for women producers and vendors. Soon, traditional vegetables featured in menus of restaurants and even in the smallest country markets.

An impact assessment estimated that the weekly gross value of African leafy vegetables in 2006 was US$1.1 million, double that of 2001, and this was largely the result of our work. Another assessment, in Kitui County, noted marked differences – both between the communities where we worked and control areas, and also before and after our activities – in dietary diversity, diversity of marketed species and attitudes towards traditional vegetables.



Many organizations are now working with traditional vegetables in Africa and beyond. With the right approach – usually a combination of research, awareness and promotion – neglected species can become part of local cuisines again and contribute significantly to nutrition, health and income.

My work to understand African food systems better, continues today, together with Dr Yasuyuki Morimoto, focusing on species documentation, dietary assessments, nutrient analyses and recipe documentation. We are developing a tool to be better able to assess and improve diets, nutrition and health using locally available agrobiodiversity.

Patrick Maundu

2011–today: Honorary Research Fellow

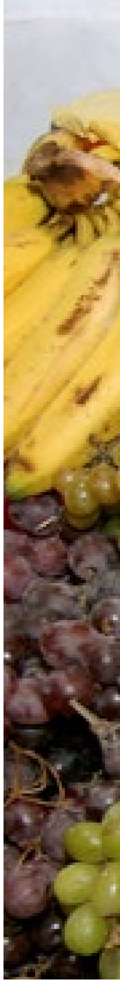
2007–2010: Coordinator, Dietary Diversity Project

2001–2006: Coordinator, African Leafy Vegetables Project

1992–1999: Partner and Scientist, Traditional Vegetables

"I am unsure of how I would be raising money for foodstuff for my family, school fees for my grandchild, and monthly contributions to our women's group, if it were not for the terere (leaf amaranth) and managu (African nightshade) that I grow and sell in Kalundu Market".

Emily Mbindya, Kyanika Village, Kitui County, Kenya



Credit: LI-BIRD/S.Subedi

How nutrition became part of the biodiversity agenda

The link between biodiversity, food and nutrition emerged from our work on the biodiversity of traditional African leafy vegetables and on the rich biodiversity maintained in home gardens around the world. Farmers often cited dietary preferences and health-promoting attributes as key factors for selecting and maintaining crop and animal diversity on farms. Even within major staple crops such as rice, we identified many cases in which specific biodiversity, such as red varieties of rice in Nepal and Vietnam, were considered medicinal. People chose, selected, maintained and consumed specific varieties for their nutritional and health benefits.

Growing awareness that agricultural biodiversity was an important factor in diets and health coincided with emerging global challenges to health. In 2004, the World Health Organization (WHO) reported that non-communicable diseases, like coronary diseases and diabetes, had emerged as the major cause of death and disability in developing countries. The WHO noted the underlying determinants of these diseases as the simplification of diets, trending to elevated consumption of energy-dense and nutrient-poor foods. Such diets may provide enough calories but not enough nutrition, resulting in 'hidden hunger'.

In order to contribute to the fight against hidden hunger, Bioversity International joined forces with nutritionists to demonstrate how and where the use of agricultural biodiversity could underpin efforts to maintain and increase dietary diversity and the consumption of healthy plant-based foods. Working with the UN Standing Committee on Nutrition and by including dietary diversity, food and nutrition security as a key objective of the 8th Conference of the Parties to the Convention on Biological Diversity in 2006, Bioversity was able to launch a global programme to investigate and promote the safeguarding and deployment of agricultural biodiversity in the fight against hidden hunger and simplified diets.

Health is an overriding and immediate concern for humanity; by being recognized for its role in improving diets, biodiversity moved from being an environmental problem, to becoming a crucial component for human health.

Bioversity's first task was to fill the gaps in knowledge about the nutritional value of many of the species, crop varieties and wild plant foods that

traditionally contribute to more diverse diets. Bioversity worked with Food and Agriculture Organization of the UN (FAO) to develop indicators for food composition and this nutritional information was added to FAO's databases of food composition. Before, these databases had little information about traditional food species and almost none about the nutritional differences between different varieties of the same species.

Bioversity's work in Benin, Brazil, Kenya, Nepal and Peru and elsewhere has shown that cultural change in favour of dietary diversity, traditional foods and safeguarding biodiversity is possible. It can even become fashionable to prefer dietary diversity; ordinary people start to demand it and that in turn can influence policy.

Much remains to be done, and the case for agricultural biodiversity as a pillar of good health has not yet been adequately made. By working together with nutritionists and health professionals we have been able to strengthen our own evidence base on where, how and when agricultural biodiversity can make a difference in improving the health and welfare of the rural and urban poor.

Pablo Eyzaguirre

2015–today: Honorary Research Fellow

1995–2014: Senior Scientist, Anthropology, Ethnobotany and Socioeconomics

Biodiversity for food and nutrition

By 2006, there was enough evidence to suggest that agricultural biodiversity made a valuable contribution to balanced, healthy diets. The Cross-cutting Initiative on Biodiversity for Food and Nutrition had just been approved by the Convention on Biological Diversity (CBD) and set out a framework for how to mainstream biodiversity for improved food and nutrition, but no country had yet explicitly and intentionally attempted to do so.

The Bioversity International-led Biodiversity for Food and Nutrition project asked: Can nutrient-rich agricultural biodiversity be mainstreamed to improve diets?

We worked in four countries – Brazil, Kenya, Turkey and Sri Lanka – each rich in biodiversity but with different political and social configurations, to generate evidence of the potential contribution of neglected food biodiversity to good nutrition. We also helped build effective partnerships to better link knowledge, policy and markets and to improve awareness and understanding.

In each country, linking up these different components, often dealt with individually in the past, started the transformation to shift the centre of gravity from essentially uniform food production systems to something that can be much more diverse, resilient and healthy. This is the power of the joined-up approach. A key success factor was to have champions for mainstreaming biodiversity who possessed the vision and gravitas to mobilize people, partners and resources. There is no prescriptive approach, no one-size-fits-all. Instead we tailored our efforts to local contexts and nuances, responding as we went along to many unanticipated opportunities and challenges.

We identified key national partners and provided them with much-needed resources, tools and support so that they could demonstrate the nutritional value of their country's biodiversity. They used that knowledge to devise novel and innovative policy solutions that incentivized the use of this biodiversity. For example, links to institutional markets such as schools and other public food procurement, backed by dietary guidelines and by great awareness-raising efforts, resulted in greater use of agrobiodiversity for nutrition.

Biodiversity for Food and Nutrition leaves a legacy of achievements including biodiversity champions, knowledge systems, innovative policies, novel procurement models and state-of-the-art approaches to awareness raising as well as a host of tools to assist other individuals and countries who might be interested in replicating our approach.

Ours was the first project with diet and nutrition objectives to be funded by the Global Environment Facility (GEF); a courageous move, but one that paid off, as it can be seen as a model for other GEF projects to mainstream agrobiodiversity. It is also the first and only GEF project thus far that falls under the CBD Cross-cutting Initiative on Biodiversity for Food and Nutrition.

Biodiversity for Food and Nutrition has demonstrated to countries that they are sitting on a rich biocultural heritage of nutrient-rich agrobiodiversity with multiple benefits, which can be effectively prioritized and mobilized, especially where there is good leadership and vision. It has hopefully opened up a crack in the current food system through which countries can see a healthier, more diverse future.

Danny Hunter

2010–today: Senior Scientist, Healthy Diets from Sustainable Food Systems, and Global Project Coordinator, GEF/Biodiversity for Food and Nutrition Project

2008–2010: Global Project Coordinator, GEF/Crop Wild Relative Project

"Bioversity International through the 'Biodiversity for Food and Nutrition' project has enabled me to learn and disseminate information in SINGI outreach projects that address the problems of malnutrition and food insecurity. I have also been able to mobilize communities, groups and individuals in issues affecting small-scale farmers, women, men, youths and self-help initiatives by disseminating effective and appropriate knowledge towards ecological organic agriculture especially promoting African leafy vegetable in schools and in communities where SINGI works."

William Buluma Odhiambo
Chairman SINGI
Field Assistant/Mobilizer Bioversity International

A new life for forgotten crops

Promoting neglected and underutilized species (NUS) faces an inherent paradox: although they are marginalized by the mainstream market, some local people nevertheless may still appreciate them for their benefits for resilience, nutrition, cultural identity and taste. At the heart of our endeavours to bring back these crops is an effort to leverage these values, so that consumers increase their demand for NUS, prompting markets to increase supply.

Crucially, our projects bring together disciplines and sources of forgotten knowledge. Local people may have forgotten how to cook and process foods, farmers how to grow and market them, retail outlets may be unfamiliar with crops and products, while urban consumers may need to learn how to make best use of them. Over the years, we have worked in many countries and on many model crops, such as rocket in Mediterranean countries, caper and laurel in Syria, nigella in Yemen, oregano and mint in Egypt, minor millets in India and Nepal, African leafy vegetables in Kenya, fonio, Bambara groundnut and jute mallow in Mali, quinoa, amaranth and cañahua in Bolivia and Peru and chaya and tepary bean in Guatemala.

We must supply products that consumers want, so the project works with partners to develop new products and recipes that showcase the special qualities of each species. In India, for example, biscuits and fried products highlight the crispy texture of foxtail millet. Little millet seeds are light and puffy, ideal for fermented foods like *'idli'* and *'dosa'*, normally prepared with rice or wheat. Elsewhere, we developed novel fortified foods combining mainstream flours with those of nutritious NUS, for example wheat and Bambara groundnut, or maize and chaya. The project has helped train thousands of people, especially women, to prepare these value-added products both to eat in their own households and to market, an effort that improves both nutrition and income security.

The project works with governments and the private sector to develop quality standards that are compatible with the conservation of agricultural biodiversity. Farmer-producer companies and other community-based associations have been created to provide high-quality seeds to farmers and larger volumes of products to markets, overcoming two common constraints. Getting NUS included in school meals and other public procurement systems – as we did for millets in India's public distribution system – is an effective strategy to mainstream these crops.

We also pursue sustainable and long-term linkages among value chain actors. For example, a joint venture in Bolivia with the coffee-shop chain 'Alexander Coffee' promoted the supply of marginalized Andean grains directly from poor rural farming communities around Lake Titicaca. More recently, women's associations in Guatemala are collaborating with professional chefs to popularize protein-rich chaya in major cities. Diversity fairs, festivals, recipe books, rural plays, community-based workshops, awareness campaigns through radio, TV, the popular press, and social media help to create awareness and thus raise demand.

Stefano Padulosi

2018–today: Research Team Leader, Rural Urban Agri-food Systems, Healthy Diets from Sustainable Food Systems Initiative

2001–today: Coordinator, IFAD NUS Programme and NUS focal point

1998–2004: Coordinator Central, West Asia and North Africa Regional Project

1993–1998: Coordinator, Underutilized Mediterranean Species Project

"Thanks to Bioversity we have learnt more practices to leverage diversity for improving our lives in the village"

Mr Lastnokhel Jalong, Kweng village, Meghalaya State, India

Food tree species in West Africa

Forest foods, including products from trees, herbs, mushrooms and animals, contribute in many ways to improving food security, supplying affordable and often highly nutritious food. Although very few communities in the world currently depend exclusively on forest foods for their complete diet, forest foods can contribute to calorie intake during lean seasons and at times of low agricultural production. Cultivating an appropriate mix of indigenous fruit tree species which fruit in different seasons, can result in a year-round supply of key nutrients. They can also be sold in times of crisis.

Bioversity International's research on food tree species in West Africa was designed to understand which edible products from trees played a significant role in the diet of rural communities and how priority food tree species could be promoted in forest landscape restoration initiatives. We wanted to know what role food tree species were playing in mitigating nutritional gaps and whether some food tree species were particularly threatened and should be prioritized for conservation and restoration efforts. I have worked particularly in Burkina Faso, to identify those food tree species whose edible products are most often consumed by the rural population and that are at the same time under threat due to forest fragmentation, habitat loss and land degradation processes.

Once we had identified priority tree species, we generated the supporting knowledge necessary to develop specific conservation measures, in collaboration with local research partners. As a basis for the design of conservation strategies, we generated potential distribution maps of food tree species, through a participatory process involving local researchers and experts. The maps helped us see where there were likely to be tree populations of particular value or regions where our targeted tree species would occur and would be under pressure from projected climatic change and other drivers of change in the landscape.

In addition, we decided to dig deeper into understanding the genetic diversity, geneflow and interactions with policy and practice of one species, néré (*Parkia biglobosa*), a highly valued multipurpose tree native to African savannahs with a large distribution range, from Senegal to Uganda. Néré is appreciated primarily for the highly nutritious condiment derived from its fermented seeds (*soumbala*). We characterized the genetic diversity of néré across its range, looked at geneflow in landscapes where croplands are expanding, and examined

the results of tree tenure practices (usually disconnected from land tenure). This gave us the information we needed to develop a conservation strategy and characterize sources of forest material for use in forest nutrition-sensitive restoration initiatives. The approach developed for this species has helped the National Tree Seed Center of Burkina Faso to refine their collection strategy of forest reproductive material for this species. The approach used represents a model that can be applied to other tree species whose conservation is supported by the National Tree Seed Center of Burkina Faso and other stakeholders.

Barbara Vinceti

2006–today: Scientist, Forest Biodiversity, Understanding and Managing Diversity Team and Europe Teams

2002–2005: Junior Professional Officer, Forest Genetic Resources Team

"Our partnership with Bioversity is good example of how international research institutes and national research institutes can work hand in hand to improve the livelihoods of rural people in the West African Sahel. This synergy has helped CNSF enhance expertise of its staff through training and joint research activities, has increased CNSF visibility through the joint production of high-quality research outputs and their dissemination, and is creating links to networks of potential partners in the area of genetic resources, natural resource management and conservation."

Dr Moussa Ouedraogo, Director of the National Tree Seed Centre (CNSF) of Burkina Faso

Tackling vitamin A deficiency with banana diversity

In Africa, bananas provide more than 25% of the carbohydrates and 10% of the daily calories for some 70 million people. Bananas are a particularly important staple crop in East Africa where, for example, in Rwanda and Burundi, average annual consumption is around 250kg to 400kg per person. The high banana germplasm diversity, the versatility of bananas, used in various forms and made into different products, and the importance of banana in diets prompted our research to establish whether banana-based systems could potentially support not only food security but also nutrition security.

A particular interest was vitamin A deficiency, a common problem in East Africa. We knew that banana varieties elsewhere in the world contained large amounts of pro-vitamin A carotenoids (pVACs – the precursors used by the body to produce vitamin A). How did the nutritional content of local commonly consumed banana varieties and their derived products compare with banana varieties and products elsewhere, and how could we ensure that populations obtained better nutrition from the bananas in their diets?

Between 2007 and 2012, my team and I first identified the contribution of bananas to diets in Uganda, Burundi and eastern Democratic Republic of Congo (DRC), where more than 60% of the people eat banana in some form at least once a day. Then, for the bulk of my PhD (2010– 2012), I analyzed common banana cultivars and their derived dishes to establish levels of pVACs retention following ripening and local processing. Although the East African banana varieties do contain pVACs, levels were considerably lower than those in cultivars from Southeast Asia and the Pacific.

This prompted us to see whether some of the more nutritious banana varieties could find a place in the farming and food systems of East Africa. We selected 12 varieties rich in pVACs from the Bioversity International *Musa* Germplasm Transit Centre in Belgium, which we thought might do well, and worked with farmers to evaluate them alongside similar local cultivars. The farmers were actively engaged in selecting their preferred cultivars and experimenting with them. One family, for example, discovered that they preferred the variety Pisang Papan cooked and served with beans than as a dessert banana, which is how people elsewhere eat it. The reverse was true for Bira, a variety that is normally cooked but that this family preferred as a dessert banana and also used to brew beer.

With our partners, we have distributed more than 15,000 plantlets of pVAC-rich varieties to farmers. We are exploring how to make best use of these nutritious bananas and have reached more than 10,000 households with this information. We have noticed rising demand, as farmers share the bananas and plants with their neighbours. Farmers in Burundi

and Eastern DRC have shared hundreds of suckers. In fact a very positive sign — at least for the project — is that some farmers have been stealing plantlets of the new varieties from their neighbours.

The next phase of our research will be to measure the actual effect of increased consumption of pVAC-rich bananas on vitamin A levels in the body, and whether this is an economically and socially effective way to tackle vitamin A deficiency.

Beatrice Ekesa

2017–today: Associate Scientist, Healthy diets from Sustainable Food Systems	
2012– 2016: Post-Doctoral Fellow	
2011–2012: PhD research Fellow	
2007–2010: Associate Expert, Nutrition	

"When the bananas reached maturity, my wife and I were happy with the good sizes of the bunches of the plantain cooking bananas especially Apantu. It has a good aroma and is particularly good when roasted. Although Pisang Papan is considered a dessert banana, I have tried cooking it and we actually prefer it that way, boiled and served with cooked beans. Bira, which is classified as a plantain that should be cooked, we like to consume as a dessert, and I have added it to the varieties that my family and I use when making beer. Adding Bira to the bananas when making beer improves the taste and aroma of the banana beer."

Mr Honore Mpayindavyi, farmer, Burundi

Mr. Honore showing some of the Vitamin A rich bananas is his field (Photo by A.Simbare/Bioversity International)

Back on the menu

What wild and underutilized foods are available in a particular context? How are they currently grown or harvested, conserved, prepared, marketed and used? What would it take to increase the contributions of these foods to food security, dietary quality and nutrition, especially for women and young children?

We have been working on these questions in Turkana County, a very dry and challenging area in Northern Kenya since 2016. In this time, we have documented 66 wild edible plant species. However, asking people to recall their dietary intake showed that consumption of these species was very low. We found similar results in southern Benin, an area characterized by high food insecurity rates, where 35% of children do not meet minimum levels of dietary diversity. There, we documented 146 edible plant species and 148 edible animal species, several of which have the potential to improve dietary quality for small children at affordable cost, if only they were consumed more.

Dietary habits are among the hardest to change, and the determinants of food choices are many and varied. So how do we get people to consume these underutilized foods and thus improve their nutrition?

Starting in 2014, our team developed an approach whereby we took the results of our surveys of edible biodiversity and dietary intake back to discuss with communities in western Kenya. We worked with community groups, guiding them to develop their own action plans and strategies to improve how they produce and consume traditional foods. This was complemented with cooking demonstrations and advice on nutrition. One year later, the proportion of children reaching minimum dietary diversity had increased from 51% to 89%, a highly significant change compared with control communities where no activities were carried out. The original community groups we worked with have now grown into farmer resource centres, actively training their fellow farmers on farm and diet diversity. They are also constructing a community seedbank to support access to quality seeds of underutilized nutritious species in Vihiga County, Kenya. Furthermore, the community seedbank will be able to help with climate change adaptation when needed.

Other activities we carry out to promote the use of underutilized foods include linking farmers who grow traditional leafy vegetables to institutional procurement programmes such as school feeding, developing supporting materials such as seasonal food calendars that show the diversity of foods available in each month, and distributing booklets with improved recipes that add biodiverse foods to common dishes.

Celine Termote

2017–today: Scientist and Kenya Country Representative

2015–2017: Associate Scientist, Agrobiodiversity and Diet Diversity

2013–2014: Research Support Officer, Nutrition and Ethnobotany

"I have benefitted from Bioversity International trainings and community activities by growing traditional leafy vegetables and legumes; and keeping poultry for meat and eggs. Through these activities, my family no longer buy vegetables and seeds especially during favourable rainy seasons. Instead, we produce our own, consume some and sell the rest to neighbours and market vendors. The money raised is added to the family budget to cater for other needs within the household."

Evans Pome Ochuto, Organizing Secretary Itumbu Community Nutrition Group, Farmer Resource Centre, Vihiga County, Kenya

Staff

Meet our Staff: Safal Khatiwada and Sonal Dsouza

Safal Khatiwada

2014–today: National Project Assistant, Nepal

I appreciate working at Bioversity International because there is a friendly working environment and all the seniors and colleagues are very supportive and always willing to help with any work or to support your professional growth. Here we all have equal opportunities to participate in different levels of activities and there is no kind of discrimination.

Sonal Dsouza

2014–today: National Programme Assistant, India

What I most appreciate about Bioversity International is that it works at the grassroots level with the farming community, despite being an international centre, to help formulate policies and programmes to conserve and document valuable genetic resources for food and agriculture. The holistic approach starting from in situ to ex situ conservation for immediate use and for posterity makes Bioversity different from other organizations. It also lays emphasis on the role of gender and crops for the future which is so important both for household nutritional and environmental security. I am indeed proud to be a part of this ever-evolving global organization serving society with a human face.

Bringing it all together

Making an impact at Bioversity

When I started at Bioversity International in 2007, the approach to impact assessment centred on individual projects, trying to establish evidence that the researchers had achieved what they set out to do. That is a good and necessary part of project management, but it does not tell us whether Bioversity as an organization is achieving its strategic objectives. For that reason, starting in 2011 under the guidance of Board Member Peter Hazell, we switched to looking at the impact of Bioversity programmes, each of which encompassed several projects.

At that point, each programme was beginning to develop an individual Theory of Change, which sets out not only the expected short-term outputs of the programme but also the outcomes, in terms of changes in behaviour, and impacts over the longer term. Crucially, a Theory of Change includes not only what should happen but also how it should happen and who else is required to make it happen. It includes clear and measurable indicators, so we can see the mechanisms by which Bioversity research gives rise to international public goods, and then how those international public goods result in changes on the ground related to our strategic objectives. When Bioversity moved to results-based management in 2013 we had the additional data to factor in the resources devoted to various aspects of the changes we seek.

Overall, we want to see how farmers can use agricultural biodiversity to increase their resilience and, as a result, reduce their vulnerability. To do that, the Development Impact Unit works with researchers to define what, in different instances, constitutes, say, resilience, and the things we need to monitor and measure to determine whether it is changing.

The 'Seeds for Needs' project, for example, is based on the fundamental idea that if farmers adopt more varieties and crops, their farms will be more resilient and their livelihoods less vulnerable. We came up with a set of indicators that together give us measures of resilience and vulnerability, and when we surveyed 600 families that had taken part in the project in Bihar state in India, we found that those who had adopted project varieties

benefited from higher yields that were less sensitive to climate-related shocks. Improved stability in the productivity of their farms led farm families to feel more empowered to respond to such disturbances. And though the project didn't actually set out to affect social cohesion, families who took part reported a greater sense of cohesion.

So we can say that this project achieved our objectives in Bihar, but one of the great problems Bioversity faces is that the use of agricultural biodiversity is very site specific. The precise methods that work in Bihar might not work elsewhere in India or on the other continents where the project operates. So we are developing standardized assessment protocols that will work across different projects and different countries, regardless of the methods each site is using. This more structured framework will allow us to draw the kind of high-level conclusions we need about the impact of Bioversity as a whole, over and above the impact of individual programmes.

Elisabetta Gotor

2006–today: Head, Development Impact Unit

Credit: LI-BIRD/S.Subedi

The Agrobiodiversity Index

Can we design an Agrobiodiversity Index that triggers action to better manage agrobiodiversity worldwide?

This was the question raised by Bioversity International scientists in 2016. Some of us worked on agrobiodiversity and nutrition, others focused more on sustainable agriculture, or improving genetic resource management systems. We realized that, though the components of agrobiodiversity were interconnected, we measured it in many different ways and we lacked a tool that brings the multiple components of agrobiodiversity together and allowed a more complete picture of what was happening with agrobiodiversity in a given setting.

Together with Bioversity's management, we reached out to many actors in the food system to explore this question. At first we were mainly interacting with governments and our more traditional partners in national agricultural research systems, but along the way the idea triggered more and more interest among companies and the finance world. This was because better management of agrobiodiversity provides opportunities to better manage risk, both operational and reputational. While this was very exciting from a user's prospective, it did add a very different layer of complexity to the design of the Agrobiodiversity Index and the type of data that could feed into it.

Building on input from various potential users, and rooted in the scientific evidence out there, we went backward and forward on the architecture of the Agrobiodiversity Index and settled on three pillars – agrobiodiversity in consumption for healthy diets, in production for sustainable agriculture, and in genetic resource management for future options. That was the relatively easy part. Harder was the selection of the indicators and the data and scales that we considered reliable and insightful enough to feed into the Agrobiodiversity Index. We identified 23 indicators and related databases that were not perfect but could get the ball rolling. We have presented the initial prototype at various

international fora and events, and it is gaining rapid traction. Based on feedback, we also included six areas of risk more explicitly into the architecture of the Agrobiodiversity Index, and clarified further the role of various actors – farmers, consumers, governments and food and agro-businesses.

We are now applying the Agrobiodiversity Index to a growing number of countries and companies. We keep learning by doing and therefore improving the methodology, the data, the various applications and the communications. We think it is a unique tool as it brings science and action together, as well as multiple sectors and multiple actors of our food systems. We really hope the Agrobiodiversity Index can help put the spotlight on agrobiodiversity as a critical part of the solution to make our food systems more sustainable.

Roseline Remans

2018–today: Senior Scientist, Productive and Resilient Farms, Forests and Landscapes & Healthy Diets from Sustainable Food systems

2014–2018: Honorary Research Fellow, Healthy Diets from Sustainable Food systems & Productive and Resilient Farms, Forests and Landscapes

If you want to know more

SAFEGUARD

Bananas

- **Websites**

The reports and catalogues for all of Bioversity's banana collection missions can be found on the MusaNet website (www.musanet.org).

ProMusa is a platform for sharing, examining and debating news and information on bananas. http://www.promusa.org/

Musapedia (www.promusa.org/musapedia) is an online compendium that taps into the vast collective knowledge on banana.

- **Papers**

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Cacao

- **Websites**

The Cocoa of Excellence Programme recognizing the work of cocoa farmers and celebrating the diversity of cocoa flavours: www.cocoaofexcellence.org

A global network for Cacao genetic resources – CacaoNet: www.cacaonet.org

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Crop wild relatives

- **Websites**

Information, models and tools for crop wild relatives can be found at the crop wild relatives global portal: http://www.cropwildrelatives.org/

- **Papers**

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Neglected and underutilized species (NUS)

- **Webpages**

The NUS community website is an on-line platform for sharing research results, development news and policy advice regarding the use and conservation of neglected and underutilized species, or NUS for short: http://www.nuscommunity.org/

- **Papers**

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On-farm and *in situ* conservation

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Bananas

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- **Material for universities**

Training materials. ioversity International, together with partners, produces training and self-learning materials on selected topics on the use and conservation of agricultural and forest biodiversity for a variety of audiences including researchers, technicians, university lecturers and policymakers. Many of the training packages include lecture support notes, exercises, notes for trainers, further reading, references, links and slides. Some materials are available in different languages. https://www.bioversityinternational.org/e-library/publications/training-materials/

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- **Toolkits**

Banana research priorities knowledge toolkit http://www.rtb-bananaresearchpriorities.org/knowledge-toolkit/

Crop wild relatives strategy toolkit http://www.cropwildrelatives.org/sadc-cwr-project/project-results/capacity-building/

Resilient seed systems resource box http://www.seedsresourcebox.org/

Toolkit for the indicators of resilience in socio-ecological production landscapes and seascapes https://www.bioversityinternational.org/e-library/publications/detail/toolkit-for-the-indicators-of-resilience-in-socio-ecological-production-landscapes-and-seascapes/

Tree diversity for restoration http://www.restool.org/en/tool.php

- **E-learning**

Online course about mainstreaming biodiversity into food and nutrition policies, programmes, food value chains and daily diets.http://www.b4fn.org/e-learning/

Descriptors

Bioversity International, in collaboration with international partners, has developed over one hundred descriptors, available from our website: https://www.bioversityinternational.org/e-library/publications/descriptors/

Networks

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PRODUCE

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Banana production

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Toolkit for the indicators of resilience in socio-ecological production landscapes and seascapes https://www.bioversityinternational.org/e-library/publications/detail/toolkit-for-the-indicators-of-resilience-in-socio-ecological-production-landscapes-and-seascapes/

Nepal

The local crop project of the Himalayan region of Nepal focuses its research and promotion work on neglected and underutilized species specifically adapted to high mountain cold environments: http://himalayancrops.org

CONSUME

African leafy vegetables

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Minor millets as a central element for sustainably enhanced incomes, empowerment and nutrition in rural India. Padulosi S, Bhag Mal, King OI, Gotor E. 2015. Sustainability 2015, 7(7), 8904-8933; doi:10.3390/su7078904 http://www.mdpi.com/2071-1050/7/7/8904

Nutrition and Health

- **Websites**

Biodiversity for Food and Nutrition, a multicountry project promoting cultivation and consumption of underutilized nutrient-rich biodiversity: http://www.b4fn.org/

The NUS community website is an on-line platform for sharing research results, development news and policy advice regarding the use and conservation of neglected and underutilized species, or NUS for short: http://www.nuscommunity.org/

- **Papers**

Connecting global priorities: biodiversity and human health: a state of knowledge review. Romanelli C, Cooper D, Campbell-Lendrum D, Maiero M, Karesh W, Hunter D, Golden C. 2015. Convention on Biological Diversity/ World Health Organization

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Thank you to our partners

Bioversity International works around many partners around the world. Our partners make it possible for us to work towards achieving our vision: a world in which agrobiodiversity nourishes people and sustains the planet and we wish to thank them for their support throughout the last 45 years and looking ahead.

Partners include: research institutes; universities; development agencies; governments; national agricultural research systems; national plant genetic resources programmes; NGOs; the private sector; schools; women's groups; international and national genebanks; local, national and global agri-food value chain actors; agricultural extension services; timber concessionaires; conservation organizations;, and farmers.

Bioversity International is a CGIAR Research Centre. CGIAR is a global partnership for a food-secure future. Its science is carried out by 15 Research Centres in close collaboration with hundreds of partners across the globe.

We also work in close partnership with the United Nations Rome-based organizations: Food and Agriculture Organization of the UN (FAO), International Fund for Agricultural Development (IFAD) and the World Food Programme.

The list below names partners related to the highlights of our work included in this book. Of course, this is just a small sample of the many, many partners who we have worked with over the last 45 years and we extend our appreciation to all of them.

Research and implementation partners

CGIAR Research Programmes

Bioversity International is proud to be a CGIAR Research Centre. Over the last 45 years, we have collaborated with our partners at our sister CGIAR Research Centres, and more recently, through CGIAR Research Programs and Platforms including:

- CGIAR Genebank Platform
- CGIAR Integrated Breeding Platform
- CGIAR Platform for Big Data in Agriculture
- CGIAR Research Program on Agriculture for Nutrition and Health
- CGIAR Research Program on Aquatic Agricultural Systems
- CGIAR Research Program on Climate Change, Agriculture and Food Security
- CGIAR Research Program on Drylands
- CGIAR Research Program on Forests, Trees and Agroforestry
- CGIAR Research Program on HumidTropics
- CGIAR Research Program on Maize
- CGIAR Research Program on Policies, Institutes and Markets
- CGIAR Research Program on Rice
- CGIAR Research Program on Roots, Tubers and Bananas
- CGIAR Research Program on Water, Land and Ecosystems
- CGIAR Research Program on Wheat
- CGIAR System-wide Genetic Resources Programme
- CGIAR System-wide Program on Collective Action and Property Rights (CAPRi)
- Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA)

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www.cgiar.org/funders/

Global/Multiple countries

- African Union Commission
- Asia Pacific Forest Genetic Resources Programme (APFORGEN)
- Banana Asia-Pacific Network (BAPNET)
- Banana Research and Development Network for Latin America and the Caribbean (MUSALAC)
- Banana Research Network for East and Southern Africa (BARNESA)
- Catholic Relief Services (CRS)
- Center for International Forestry Research (CIFOR)
- Central American Agricultural Council
- Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)
- Centre for African Bio-Entrepreneurship (CABE)
- Centro Agronómico Tropical de Investigación y Enseñanza (CATIE)
- Commission on Genetic Resources for Food and Agriculture
- Common Market for Eastern and Southern Africa (COMESA)
- Community Technology Development Trust (CTDT)
- Crop Trust
- East African Community (EAC)
- Economics of Ecosystems and Biodiversity (TEEB)
- European Cooperative Programme for Plant Genetic Resources (ECPGR)
- European Forest Genetic Resources Programme (EUFORGEN)
- Fairtrade International
- Food and Agriculture Organization of the UN (FAO)
- Global Partnership Initiative for Plant Breeding
- Hivos
- Indigenous Partnership for Agrobiodiversity and Food Sovereignty (Indigenous Partnership)
- Institute for Global Environmental Strategies (IGES)
- Integrated Seed Sector Development (ISSD) Africa
- Inter-American Institute for Cooperation on Agriculture (IICA)
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)
- International Atomic Energy Agency (IAEA)
- International Center for Agricultural Research in the Dry Areas (ICARDA)
- International Center for Tropical Agriculture (CIAT)
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
- International Food Policy Research Institute (IFPRI)
- International Fund for Agricultural Development (IFAD)
- International Institute of Tropical Agriculture (IITA)
- International Livestock Research Institute (ILRI)
- International Maize and Wheat Improvement Center (CIMMYT)
- International Partnership for the Satoyama Initiative
- International Potato Center (CIP)
- International Rice Research Institute (IRRI)
- International Society for Horticultural Science (ISHS)
- International Treaty for Plant Genetic Resources for Food and Agriculture Secretariat (ITPGRFA)
- International Union for the Conservation of Nature (IUCN)
- International Water Management Institute (IWMI)
- ISEAL Alliance
- Latin American Forest Genetic Resources Network (LAFORGEN)
- Rainforest Alliance
- Regional network for West and Central Africa (MUSACO/ Innovate Plantain)
- Save the Children International
- Secretariat of the Convention on Biological Diversity
- Secretariat of the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture
- Sub-Saharan African Forest Genetic Resources Programme (SAFORGEN)

- Trocaire
- UN Development Programme (UNDP)
- UN Environment
- UN Standing Committee on Nutrition
- United Nations University (UNU)
- World Agricultural Heritage Foundation (WAHF)
- World Agroforestry Center (ICRAF)
- World Food Programme
- World Vegetable Center (AVRDC)
- WorldFish

Algeria
- National Agricultural Research Institute

Armenia
- Ministry of Nature Protection of Armenia
- National Agricultural Research System

Australia
- Australian Centre for International Agricultural Research
- Department of Agriculture, Fisheries and Forestry (DAFF)
- Department of Foreign Affairs and Trade
- University of Queensland (UQ)

Austria
- Austrian Research Centre for Forests (BFW)
- Graz University of Technology
- University of Natural Resources and Life Sciences (BOKU)
- University of Vienna

Bangladesh
- Bangladesh Agricultural Research Institute
- Unnayan Bikalper Nitinirdharoni Gobeshona (UBINIG)

Belgium
- Botanic Garden Meise
- Flemish Institute for Technological Research (VITO NV)
- KU Leuven
- University of Gembloux
- University of Ghent
- University of Liege

Benin
- Cercle de Sauvegarde des Ressources Naturelles (CeSaReN)
- Institut National des Recherches Agricoles du Bénin (INRAB)
- University of Abomey-Calavi

Bhutan
- National Biodiversity Centre

Bolivia
- National Agricultural Research System
- Fundación Promoción e Investigación de Productos Andinos (PROINPA)

Bosnia and Herzegovina
- University of Banja Luka

Botswana
- Botswana College of Agriculture (BCA)

Brazil
- Brazilian Biodiversity Fund (FUNBIO)
- Empresa Brasileira de Pesquisa Agropecuária (Embrapa)
- Ministry of Health
- Ministerio do Meio Ambiente, Secretaria de Biodiversidade e Florestas

Burundi
- Institut des Sciences Agronomiques du Burundi (ISABU)

Burkina Faso
- Centre National de Semences Forestières (CNSF)
- Commission Nationale de Gestion des Ressources Phytogénétiques (CONAGREP)
- Institut de l'Environnement et de la Recherche Agricole (INERA)
- Institut de Recherche en Sciences Appliquées et Technologies (IRSAT)
- SNV World
- Tiipaalga
- University of Ouagadougou

Cambodia
- Cambodian Agricultural Research and Development Institute

Cameroon
- African Research Centre on Bananas and Plantains
- Institute of Agricultural research for Development, Ekona
- University of Dschjang

Canada
- Commonwealth of Learning

Central African Republic
- Central African Agricultural Research Institute

China
- Chengdu Institute of Biology of Chinese Academy of Sciences
- Chinese Academy of Agricultural Sciences (CAAS)
- Chinese Institute of Geographic Sciences and Natural Resources Research (IGSNRR) of the Center for Natural and Cultural Heritage (CNACH)
- Farmers' Seed Network
- Green Seed Ecological Cultural Development
- Huazhong Agricultural University, Wuhan
- Liangshan Prefecture Xichang Agricultural Research Institute
- National Genebank
- Shanxi Academy of Agricultural Sciences
- Sichuan Academy of Agricultural Sciences

- Yunnan Academy of Agricultural Sciences
- Yunnan Agricultural University (YAU)

Colombia
- AGROSAVIA
- Federación Nacional de Plataneros de Colombia (FEDEPLATANO)
- Forestpa
- Universidad Nacional (Medellin and Palmira)

Comores
- Institut National de Recherche pour l'Agriculture, la Pêche et l'Environnement (INRAPE)

Congo, Democratic Republic of the
- Institut National pour l'Etude et la Recherche Agronomique (INERA)
- Université Catholique du Graben, Butembo
- Université de Kisangani (UNIKIS)
- University of Kinshasa

Costa Rica
- Corporación Bananera Nacional (CORBANA)
- Comisión Nacional de Semillas
- Ministry of Agriculture and Livestock (MAG)
- National Agricultural Research System

Côte d'Ivoire
- Centre National de Recherche Agronomique (CNRA)
- University of Côte d'Ivoire

Cuba
- Centro Nacional de Áreas Protegidas (CNAP)/Ministerio de Ciencia, Tecnología y Medio Ambiente (CITMA)
- Instituto de Investigaciones Fundamentales en Agricultura Tropical (INIFAT)
- Research Institute of Tropical Root and Tuber Crops (INIVIT), from the Agriculture Ministry of the Cuban Republic

Czech Republic
- Institute of Experimental Botany (IEB)

Dominican Republic
- Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF)

Ecuador
- Instituto Nacional de Investigaciones Agropecurarias (INIAP)

Egypt
- National Agricultural Research System

El Salvador
- National Agricultural Research System

Ethiopia
- Amhara Region Agricultural Research Institute (ARARI)
- Ethiopian Biodiversity Institute (EBI)
- Ethiopian Institute of Agricultural Research
- Mekelle University

Fiji
- Ministry of Agriculture
- Secretariat of the Pacific Community (SPC)

Finland
- University of Helsinki

France
- Institut de Recherche pour le Développement (IRD)
- Institut national de la recherche agronomique (INRA)

Gabon
- Cenarest
- Research Institute for Tropical Ecology (IRET)

Germany
- Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
- Hohenheim University
- Humboldt Institute
- Julius Kühn-Institut (JKI)
- Leibniz Institute of Plant Genetics and Crop Plant Research (IPK)
- University of Bonn

Ghana
- Crops Research Institute (CSIR-CRI)
- Ghana Cocoa Board (COCOBOD)

Guadeloupe
- National Agricultural Research Council

Guatemala
- Action Against Hunger
- Asociación de Comunidades Forestales de Petén (ACOFOP)
- Asociación de Organizaciones de los Cuchumatanes (ASOCUCH)
- Consejo Nacional de Areas Protegidas (CONAP)
- Mancomunidad Copanch'orti'
- Ministry of Agriculture, Livestock, and Food (MAGA)
- National Agricultural Research System
- Universidad del Valle de Guatemala (UVG)

Honduras
- La Fundación para la Investigación Participativa con Agricultores de Honduras (FIPAH)
- National Agricultural Research System

India

- Action for Social Advancement (ASA), Bhopal, Madhya Pradesh
- Centre for Advanced Research and Development (CARD)
- Deendayal Research Institute Krishi Vigyan Kendra
- Dindori Tribal Farmer Producer Company
- Foundation for Development Intergration, Assam
- Gene Campaign
- GPS Institute of Agricultural Management
- Gramin Vikas Vigyan Samiti, Rajasthan
- Green Cause Foundation
- Himalayan Research Group, Himachal Pradesh
- Humana People to People
- IFAD Loan Tejaswini Rural Women Empowerment Programme, Madhya Pradesh
- Indian Council of Agricultural Research (ICAR)
- Indian Institute of Horticultural Research (IIHR)
- Indira Gandhi Krishi Vishwavidyalaya, Chhatisgarh
- IORA Ecological Solutions
- Kerala Agricultural University (KAU)
- Krishi Vigyan Kendra, Raisen
- LIFE Trust
- Lok Chetna Manch, Uttarakhand
- M.S. Swaminathan Research Foundation (MSSRF)
- Madhyabharat Consortium of Farmers Producer Company Limited (MBCFPCL)
- Maheshmati Tribal Farmer Producer Company
- Mandla Tribal Farmers Producer Company
- Mount Valley Development Association, Uttarakhand
- National Bureau of Plant Genetic Resources (NBPGR)
- National Institute of Nutrition
- National Research Centre on Banana (ICAR-NRCB)
- North East Slow Food and Agrobiodiversity Society, Meghalaya State
- Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Madhya Pradesh
- Research Institute of Horticulture, Viticulture and Wine-making named after acad. M. Mirzaev
- Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST-K)
- Srishti Institute of Art, Design and Technology
- University of Horticultural Sciences (UHS), Bagalkot, Karnataka
- YSR Horticultural University, Andhra Pradesh

Indonesia

- Agricultural Environment Research Institute
- Asian and Pacific Coconut Community (APCC)

Italy

- Rete Semi Rurali
- Scuola Superiore Sant'Anna
- University of Naples
- University of Roma TRE
- Università degli studi di Milano (UniMi)
- World Biodiversity Association

Jamaica

- Banana Board

Kazakhstan

- Academy of Agricultural Sciences

Japan

- Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture
- Ministry of Agriculture, Forestry and Fisheries (MAFF)

Kenya

- Australian Centre for International Agricultural Research (ACIAR)
- Centre for African Bio-Entrepreneurship (CABE)
- Colby College
- Egerton University
- Fairtrade Africa
- Food and nutrition linkages group, Ministry of Health, Nutrition department
- Fresh Studio
- Genetic resources Research Institute (GeRRI)
- GIZ Kenya
- Jomo Kenyatta University of Agriculture and Technology (JKUAT)
- Kenya Agriculture and Livestock Research Organization (KALRO)
- Kenyatta University
- Kyanika Adult Women's Group (KAWG)
- Locally operating NGOs, Vihiga County
- Lutheran World Relief
- Maseno University
- Ministries of Health and Agriculture in Vihiga and Turkana Counties
- Ministry of Agriculture, Kenya
- Ministry of Agriculture, Livestock and Fisheries Vihiga County
- Ministry of Health Vihiga County
- National Genebank of Kenya, Kenya Agricultural Research Institute
- National Museums of Kenya
- Sustainable Agriculture and Natural Resource Management Africa (SANREM-AFRICA)
- University of Nairobi
- WeRATE (Western Region Agriculture and Technology Evaluation)

Korea, Republic of

- Rural Development Administration

Kyrgyzstan

- Kyrgyz Innovation Centre of Phytotechnologies
- Kyrgyz National Agrarian University

Lao People's Democratic Republic

- National Agricultural Research System

Lebanon
- American University of Beirut

Luxembourg
- Luxembourg Institute of Science and Technology (LIST)

Madagascar
- National Center for Applied Research on Rural Development (FOFIFA)
- Service d'Appui à la Gestion de l'Environnement (SAGE)

Malaysia
- Malaysian Agricultural Research and Development Institute

Mali
- Association Aide au Sahel et l'Enfance Malienne
- Association des Conseillers Agricoles du Sahel
- Environnement et Développement du Mali (ENDA)
- Fondation pour le Développement au Sahel (FDS)
- Institut d'Economie Rurale (IER)
- Unité Service Coopération (USC)

Malawi
- Agricultural Research Council
- Small Producers and Transporters Association (SPRODETA)
- Lilongwe University of Agriculture (LUANAR)

Malaysia
- Malaysian Agricultural Research and Development Institute (MARDI)
- National University of Malaysia (UKM)
- Sarawak Biodiversity Centre
- Universiti Putra Malaysia

Mali
- Association Salvan-Enfants (ASEM)
- Centre d'Appui à l'Autopromotion pour le Développement (CAAD)
- Institut d'Economie Rurale (IER)
- National Agricultural Research System

Mauritius
- Agricultural Research and Extension Unit (AREU)
- Food and Agricultural Research and Extension Institute (FAREI)
- University of Mauritius

Mexico
- Instituto Nacional de Investigaciones Forestales, Agrí¬colas y Pecuarias

Morocco
- Institut Agronomique et Vétérinaire Hassan II
- National Agricultural Research Institute

Myanmar
- Department of Agricultural Research

Nicaragua
- Nicaragua National Agricultural Research Organization (NARO)
- Universidad Nacional Autónoma de Nicaragua (UNAN)
- Universidad Nacional Agraria

Nepal
- Local Initiatives for Biodiversity, Research and Development (LI-BIRD)
- Nepal Agricultural Research Council (NARC)

Netherlands
- Agrofair/TASTE – Technical Assistance for Sustainable Trade & Environment
- Centre for Development Innovation, Wageningen University
- Centre for Genetic Resources the Netherlands (CGN), Wageningen University
- ILEIA
- Nestlé Research Center (NRC)
- Netherlands Ministry of Foreign Affairs (DGIS)
- Original Beans
- Royal Tropical Institute (KIT)
- Wageningen University

Nicaragua
- National Agricultural Research System

Niger
- Abdou Moumouni University
- Institut National de la Recherche Agronomique du Niger (INRAN)

Nigeria
- National Horticultural Research Institute

Panama
- Instituto de Investigación Agropecuaria de Panamá (IDIAP)
- National Agricultural Research System

Papua New Guinea
- Kokonas Industri Koporisin (KIK)
- National Agricultural Research Institute (NARI)

Peru
- Instituto Nacional de Innovación Agraria (INIA)
- Inter-American Institute for Cooperation on Agricultural (IICA)
- Ministerio de Agricultura y Riego (MINAGRI)
- Ministerio del Ambiente (MINAM)
- National Forest Service and Wildlife (SERFOR)
- Naturaleza y Cultura Internacional
- Oikos – Cooperation and Development, Peru
- Original Beans
- Regional Government (GORE), Cusco
- Regional Government (GORE), Puno
- Sociedad Peruana de Derecho Ambiental
- Universidad de Piura (UDEP)
- Universidad Nacional Agraria La Molina (UNALM)
- Universidad Nacional del Altiplano (UNA)

Philippines
- Bureau of Agricultural Research
- Bureau of Plant Industry
- College of Agriculture and Food Science (CAFS/UPLB)
- Kiangan Community Multi-Purpose Development Cooperative
- Philippine Coconut Authority
- Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (PCAARRD)
- University of the Philippines Los Baños

Portugal
- Banco Português de Germoplasma Vegetal

Puerto Rico
- USDA

Rwanda
- Gardens for Health International (GHI)
- Rwanda Agriculture Board (RAB)

Samoa
- Ministry of Agriculture and Fisheries

Senegal
- Centre pour le Developpement de l'Horticulture
- Institut Sénégalais de Recherches Agricoles

Serbia
- Institute of Field and Vegetable Crops

Slovenia
- Agricultural Institute of Slovenia – Kmetijski inštitut Slovenije (KIS)

Spain
- Instituto Nacional de Investigacion y Tecnologia Agraria y Alimentaria (INIA)

South Africa
- Agricultural Research Council – Roodeplaat Vegetable and Ornamental Plant Institute/ Tropical and Subtropical Crops Division
- Department of Agriculture, Forestry and Fisheries

Sri Lanka
- Information and Communication Centre (ICC), Department of Agriculture
- Ministry of Environment
- Ministry of Mahaweli Development and Environment
- National Agricultural Research System
- Plant Genetic Resources Centre (PGRC)

Sudan
- Agricultural Plant Genetic Resources Conservation and Research Centre (APGRC)

Sweden
- EAT Foundation/Nordic Genetic Resource Centre (NordGen)
- Stockholm Resilience Centre

Switzerland
- Clarmondial AG
- Institut Universitaire d'Etudes du Développement
- Nestec Ltd./Nestlé
- Nestlé Research Center
- Pro-Specie Rara

Tajikistan
- Institute of Horticulture – Tajik Academy of Agricultural Sciences
- Scientific-Production Association 'Bogparvar'

Tanzania
- National Plant Genetic Resources Centre
- Sokoine University of Agriculture
- Tanzania Agricultural Research Institute
- Zanzibar Agricultural Research Institute

Thailand
- Biodiversity-Based Economy Development Office (BEDO)
- National Agricultural Research System
- PASD – Pgaz K'Nyau Association for Sustainable Development

Tunisia
- Association for the Safeguard of the Medina of Gafsa (ASM Gafsa)
- National Agricultural Research Institute

Turkey
- Aegean Agricultural Research Institute
- Akseki Chamber of Agriculture (Antalya)
- Alaçatı Art and Culture Association
- Association of Siyez Producers
- Association of Turkish Dieticians
- Ministry of Agriculture and Rural Affairs, General Directorate of Agricultural Research
- Ministry of Food, Agriculture and Livestock (MFAL)
- Ministry of Health
- University of Akdeniz
- University of Gazi
- University of Selçuk

Turkmenistan
- Academy of Sciences of Turkmenistan

Uganda

- Arizona State University
- Entebbe Botanic Gardens
- International Foundation of Science
- Makerere University
- Ministry of Energy and Mineral Development
- Ministry of Health
- National Agricultural Organization’s Plant Genetic Resources
- National Agricultural Research Laboratories
- National Agricultural Research Organization (NARO)
- National Agriculture Research Institute

United Kingdom

- East Malling Research
- King’s College London
- Leeds University
- Millennium Seed Bank
- Newcastle University
- Royal Botanical Garden, Kew
- University of Birmingham
- University of Bristol
- University of East Anglia
- University of Reading

United States of America

- Earth Institute at Columbia University
- Lutheran World Relief (LWR)
- National Center for Ecological Analysis and Synthesis (NCEAS)
- National Genebank
- Natural Capital Project, Stanford University
- United States Department of Agriculture (USDA)
- University of California, Berkeley
- University of Minnesota
- Versant Vision
- Washington State University

Uzbekistan

- Institute of Genetics and Plant Experimental Biology
- Uzbek Republican Scientific and Production Centre of Ornamental Gardening and Forestry
- Uzbek Research Institute of Horticulture

Vietnam

- Center of Agriculture Research and Ecological Studies (CARES)
- Fruit and Vegetable Research Institute (FAVRI)
- Hanoi Agricultural University (HAU)
- HealthBridge Foundation of Canada in Hanoi
- National Agricultural Research System
- National Institute of Nutrition

Yemen

- National Agricultural Research System

Zambia

- Community Technology Development Trust (CTDT)
- McGill University
- Ministry of Agriculture and Livestock
- Naliendele Agricultural Research Institute (NARI)
- Self Help Africa
- University of Zambia (UNZA)
- Zambia Agriculture Research Institute (ZARI)

Zimbabwe

- Community Technology Development Trust (CTDT)
- Horticultural Research Institute, Morondera
- National Plant Genetic Resources Center
- Southern Alliance for Indigenous Resources (SAFIRE)

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- Center for International Forestry Research (CIFOR)
- HarvestPlus
- International Center for Agricultural Research in the Dry Areas (ICARDA)
- International Center for Tropical Agriculture (CIAT)
- International Food Policy Research Institute (IFPRI)
- International Institute of Tropical Agriculture (IITA)
- International Maize and Wheat Improvement Center (CIMMYT)
- International Potato Center (CIP)
- International Water Management Institute (IWMI)
- System-wide Genetic Resources Policy
- Generation Challenge Program
- Worldfish
-

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- Barry Callebaut
- Bill & Melinda Gates Foundation
- Biovision Foundation
- Christensen Fund
- CocoaTown
- David and Lucile Packard Foundation
- Ecopetrol
- Federation of Cocoa Commerce
- Fondation Prince Albert II de Monaco
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- RSF Social Finance
- Seguine Cacao, Cocoa and Chocolate
- Swift Foundation
- World Cocoa Foundation
- WYG International Limited

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- Belgium
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  - Service Public Federal Sante Publique
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  - Institute of Plant Genetic Resources 'K. Malkov' Burundi
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  - International Development Research Centre (IDRC)
  - McGill University
- Catholic Relief Services (CRS)
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  - Chinese Ministry of Agriculture
  - Chinese Ministry of Science and Technology
  - National Natural Science Foundation
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- Cocoa Research Centre of the University of the West Indies
- Common Fund for Commodities (CFC)
- Congo Basin Forest Fund
- Convention on Biological Diversity
- Croatia
  - Ministry of Agriculture
- Crop Trust
- Cyprus
  - Agricultural Research Institute, Ministry of Agriculture
- Czech Republic
  - Ministry of Agriculture
- Democratic Republic of Congo
- Denmark
  - Ministry of the Environment and Food
  - Nature Agency
- Drivers of Food Choice
- Ecuador
- Estonia
  - Ministry of Agriculture
  - Ministry of the Environment
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- European Cocoa Association (ECA)
- European Union
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  - Ministry of Foreign Affairs
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- Food and Agriculture Organization of the UN/Global Environment Facility (FAO-GEF)
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- Georgia
  - Academy of Agricultural Sciences
- Germany
  - Advisory Service on Agricultural Research for Development (BEAF)
  - Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)
  - Federal Ministry of Food and Agriculture

- Global Environment Facility (GEF)
- Global Environment Facility (GEF)/UN Environment
- Global Environment Fund
- Greece
  - Agricultural Policy and Management of European Funds, Ministry of Rural Development and Food
- Hungary
  - Department of Forestry and Game Management, Ministry of Agriculture
- Iceland
  - Icelandic Forest Service
  - Ministry of Industries and Innovation
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- Integrated Seed Sector Development (ISSD)
- InterAmerican Institute for Global Change Research (IAI)
- International Cocoa Organisation (ICCO)
- International Fund for Agricultural Development (IFAD)
- International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA)
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- Ireland
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- Israel
  - Ministry of Agriculture and Rural Development
- Italy
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  - Ministry of Agriculture and Forestry
  - Ministry of Foreign Affairs and International Cooperation
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  - Kenya Society of Ethnoecology
- Latvia
  - Ministry of Agriculture
- Lithuania
  - Ministry of the Environment
  - State Forest Service
- Luxembourg
  - Nature Conservation Agency, Minister of the Environment
- Malaysia
  - Sarawak State Government
- Mali
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  - Forest Research and Management Institute
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  - Phytosanitary Directorate, Government of Montenegro
- Morocco
- Netherlands
  - Centre for Genetic Resources, The Netherlands (CGN)
  - Directorate-General for International Cooperation (DGIS)
  - Wageningen University ALTERRA
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- Norway
  - Norwegian Institute of Bioeconomy (NIBIO)
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- Poland
  - Ministry of Agriculture and Rural Development
  - Ministry of the Environment
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- Programme de Promotion de L'Exploitation Certifiée des Forêts (PPECF)
- Romania
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- Republic of Korea
  - Forest Ecosystem Restoration Initiative (FERI)
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- Rwanda
- Serbia
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- Slovakia
  - Ministry of Agriculture and Rural Development of the Slovak Republic
- Slovenia
  - Ministry of Agriculture, Forestry and Food
  - Ministry of the Environment
- Spain
  - Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
- South Africa
- Sri Lanka
- Sweden
  - Ministry for Rural Affairs, Animal and Food Division
  - Ministry of Enterprise and Innovation
  - Swedish International Development Cooperation Agency (SIDA)
- Switzerland
  - Federal Department of Economic Affairs FDEA
  - Federal Office for the Environment (FOEN)
  - Swiss Agency for Development and Cooperation (SDC)
- Thailand
- Trócaire
- Tunisia
- Turkey
  - Ministry of Agricultural Researches and Policies
  - Ministry of Forest and Water Affairs, Forest Tree Seeds and Tree Breeding Research Directorate
- Uganda
- Ukraine
  - National Centre of Plant Genetic Resources, National Academy of Agricultural Sciences of Ukraine
- United Kingdom
  - Darwin Initiative
  - Economic and Social Research Council and the Department for International Development (ESRC-DFID)
  - Forestry Commission
  - Genetic Resources Department for Environment, Food and Rural Affairs

- United Nations Environment Programme/Global Environment Facility (UNEP-GEF)
- United Nations Development Programme - Global Environmental Finance (UNDP-GEF)
- United Nations Development Programme (UNDP)
- United Nations Educational, Scientific and Cultural Organization (UNESCO)
- United Nations Environment Programme (UN Environment)
- United Nations University
- United Nations University Institute for the Advanced Studies of Sustainability (UNU-IAS)
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  - Smithsonian Tropical Research Institute
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- World Bank
- World Resources Institute (WRI)

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We deliver scientific evidence, management practices and policy options to use and safeguard agricultural and tree biodiversity to attain sustainable global food and nutrition security. We work with partners in low-income countries in different regions where agricultural and tree biodiversity can contribute to improved nutrition, resilience, productivity and climate change adaptation.

Alliance

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